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AH-64D Apache Longbow Aircrew Workload Assessment for Unmanned Aerial System (UAS) Employment

by David B. Durbin and Jamison S. Hicks

ARL-TR-4707 **January 2009**

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14. ABSTRACT
This study assessed whether workload was tolerable for AH-64D pilots when they employed an unmanned aerial system (UAS) during simulated missions. Ten AH-64D pilots participated in the study. Pilot workload, situation awareness, crew coordination, crewstation interface, switch actuations, simulator sickness, visual gaze and dwell times (using a head-eye tracker), audio-video, and tactics, techniques and procedures data were collected and analyzed. Pilot workload was found to be tolerable for the tasks they performed during the simulated missions. The workload ratings provided by the pilots were lower than the Objective and Threshold workload ratings requirements listed in the AH-64D Apache Longbow Block III Capability Development Document. Pilots reported that employing the UAS increased their overall task workload, but the situation awareness provided by the UAS sensor decreased the workload required to detect and engage targets and decreased overall target engagement timelines.

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AH-64D, unmanned aerial system, crewstation, workload, situation awareness, eye tracker

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1. Introduction

1.1 Background

The AH-64D Apache Longbow Block III upgrade program will provide aircrews with the capability to conduct level II (receive unmanned aerial system (UAS) sensor video), level III (control UAS sensor), and level IV (control of UAS sensor and air vehicle) interoperability with an UAS during missions. Aircrews will employ the UAS as a remote sensor, adding an additional sensor capability to the AH-64D reconnaissance and targeting systems. Testing has established that AH-64D aircrews can perform basic UAS operations from the crewstation during flight; however, there has been no comprehensive examination of the impact of UAS operations on aircrew workload.

The U.S. Army Research Laboratory (ARL), Human Research and Engineering Directorate (HRED) conducted an assessment of mental workload that AH-64D aircrews experienced when controlling an UAS during simulated missions. The assessment was conducted to determine if the pilot (PI) and copilot-gunner (CPG) experienced tolerable workload while they controlled an UAS and performed standard flight and mission tasks (e.g., navigation, communication) during missions. The assessment also addressed the workload requirement listed in the AH-64D Block III (AB3) Capability Development Document (CDD). The CDD requirement is that "Longbow Block III crewstation management and cognitive decision aiding systems must provide a workload environment for the crew with a Bedford workload rating not to exceed 6.0 (Threshold) and 5.0 (Objective)."

1.2 System Description

The AH-64D Apache is a twin-engine, tandem-seat, aerial weapons platform built by Boeing Integrated Defense Systems. Aircraft armament includes a belly-mounted slewable 30-mm chain gun, Hellfire missiles, and 2.75 in. aerial rockets. The aircraft integrated sensor suite includes a mast-mounted Longbow fire control radar (FCR) and a nose-mounted modernized target acquisition designation sight/pilot night vision sensor (MTADS/PNVS). There are two multi-purpose displays (MPDs) in each cockpit; the MTADS electronic display and control in the CPG crewstation; and the integrated helmet and display sight system. The aircraft has a flight control system with a fully articulated, four-bladed main rotor system. The flight control system consists of conventional cockpit controls: cyclic, collective, and pedals connected mechanically to hydromechanical actuators for the main and tail rotors; a limited authority automatic stabilization system; and an electrically actuated stabilator.

The Block III Apache is a modernized version of the AH-64D Block II Apache aircraft. The design incorporates technology advancements from other development programs and advances in processing technology since the fielding of the Block I and II AH-64D Apache. The planned upgrades should result in improved aircraft performance, reduced operating costs, and improved mission performance. One of the major upgrades is the provision for control of an UAS. Integration of the Tactical Common Data Link (TCDL) in the AH-64D will provide the aircrew with the capability of level II, level III, and level IV control of an UAS.

1.3 Assessment Overview

The assessment consisted of operational missions conducted by Apache aircrews in the AH-64D Risk and Cost Reduction Simulator (RACRS). The simulator was modified to represent the UAS Level 2-4 functionality to the maximum extent practicable based on the maturity of the Apache Block III design at the time of the assessment.

Pilots received two days of training prior to the beginning of the assessment. The training consisted of classroom instruction and hands-on flight training in the RACRS. The pilots flew the same types of missions during training that they later flew during the record trials. The mission scenario was based on a battlefield environment simulating southwest Asia. Each successive mission increased in difficulty in order to impose progressively greater workload on the pilots. The aircrews performed specific Aircrew Training Manual (ATM) tasks during each mission (appendix A). Each ATM task had prescribed conditions and standards to which both crewmembers had to perform to help ensure mission accomplishment.

During the formal evaluation, the aircrews performed Air Escort missions. The mission scenarios were developed by the Training and Doctrine Command (TRADOC) Capability Manager, Reconnaissance Attack (TCM RA) office in Fort Rucker, AL. The scenarios were developed in accordance with established aircraft tactics, techniques, and procedures (TTP).

The pilots completed the Simulator Sickness Questionnaire (SSQ) before and after each flight. They also completed the Bedford Workload Rating Scale (BWRS), the Situation Awareness Rating Technique (SART), and the UAS-Crewstation Interface (UCI) questionnaire after each mission. During each mission, the CPG wore an eye tracker, which was used to assess pilot visual workload. In addition to the pilot data, subject matter experts (SMEs) provided an independent assessment of aircrew workload, situation awareness (SA), and mission success. The SMEs completed an aircrew workload, SA, and mission success survey after each mission. A mission debriefing and after-action review (AAR) were completed after each mission.

During the simulation, aircrew actions within the cockpit were recorded for post-test analysis. Video recordings of each crewstation and all displays were kept as a permanent record. All button presses, switch activations, and MPD page displays were recorded during the simulation.

1.4 RACRS Cockpits

The RACRS cockpits consisted of high fidelity aircraft flight controls and displays (figures 1 and 2). The CPG used Target Acquisition and Designation System (TADS) Electronic Display and Control (TEDAC) grips to select and control the sensor's field of view, azimuth, elevation, gain, and level. These controls were also selectable for adjustment of the UAS sensor. The TEDAC and MPD displays were used to monitor the sensor view from the Apache and/or the UAS.

Figure 1. Apache RACRS simulator (Camber Corp).

Figure 2. Apache RACRS CPG cockpit (Camber Corp).

1.5 One Semi-Automated Forces (OneSAF)

The OneSAF simulation provided the ability to generate threats and targets on the battlefield. Scenarios were developed that incorporated the detection, identification, and acquisition of simulated threats and targets. OneSAF produced outputs on the simulation network that enabled all connected simulations to receive and display the threats and targets.

1.6 UAS Control Station

A stand-alone workstation (figure 3) was developed to allow the UAS operator to independently fly an UAS during the scenarios. This was a desktop computer with visual system representing the same terrain location as the RACRS. A commercial joystick and keyboard provided user input for UAS control. The operator was linked with the Apache crew via audio communications using the existing lab intercom. The UAS positional information was output onto the simulation network allowing the other components (e.g., wingman) to be aware of its location.

Figure 3. UAS control station (Camber Corp).

1.7 AH-64 #2 Control Station

A stand-alone workstation (figure 4), similar to the UAS control station, was developed to allow an operator to independently fly a second AH-64 (wingman) during the scenarios. This was a desktop computer with visual system representing the same terrain location as the Apache

simulation. A commercial joystick and keyboard provided user input for the second AH-64 control. The operator was linked with the Apache crew via audio communications using the existing lab intercom. The AH-64 positional information was output onto the simulation network allowing the other components to be aware of its location.

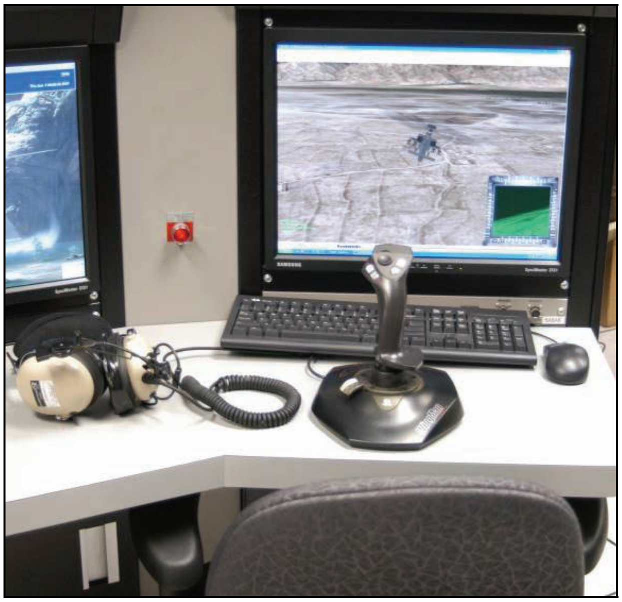

Figure 4. AH-64 #2 control station (Camber Corp).

1.8 Terrain Location

The simulator visual system was configured to fly the existing Bagram, Afghanistan, visual database (figure 5). This is a geo-specific large gaming area built from satellite acquired high-resolution imagery and detailed terrain relief. It also contained several terrain and cultural features to increase realism for the Apache pilots.

Figure 5. Apache RACRS Afghanistan database screenshot (Camber Corp).

2. Method

2.1 Data Collection

Pilot workload, SA, crew coordination, UAS crewstation interface, switch actuations, simulator sickness, visual gaze and dwell times (head-eye tracker), audio-video, and TTP data were collected and analyzed. These areas were assessed to determine if (1) pilot workload was tolerable when interacting with an UAS, (2) pilot workload in the AH-64D was higher, lower, or comparable to pilot workload when not interacting with an UAS, (3) pilots have adequate SA when interacting with the UAS, (4) the UAS control interface was easy to understand and navigate, and (5) pilots experienced simulator sickness symptoms. The data were used to recommend design improvements to the UAS menu system, training, and associated switchology and to refine TTP.

The BWRS, SART, UCI, SSQ, and SME questionnaires were developed in accordance with published guidelines for proper format and content (O'Brien and Charlton, 1996). A pre-test was conducted to refine the questionnaires and ensure that they could be easily understood and completed by the pilots and SMEs.

The pilots completed the workload, UCI, and SA questionnaires after each mission. The pilots completed the SSQ before and after each mission. The SMEs completed workload, SA, crew coordination, and mission success questionnaires after each mission. Additional data were obtained from the pilots and the SMEs during post-mission discussions and AARs. Questionnaire results were clarified with information obtained during post-mission discussions and the AARs.

2.2 Demographics

A demographics questionnaire was used to collect basic information on each pilot's experience and flight qualifications. The demographic data documented the range of pilot experience levels and qualifications.

2.3 Assessment of Crew Workload

A common definition of pilot workload is "the integrated mental and physical effort required to satisfy the perceived demands of a specified flight task" (Roscoe, 1985). It is important to assess pilot workload because mission accomplishment is related to the mental and physical ability of the crew to effectively perform their flight and mission tasks. If one or both pilots experience

excessively high workload while performing flight and mission tasks, the tasks may be performed ineffectively or abandoned. In order to assess whether the pilots are task-overloaded during the missions, the level of workload for each pilot must be evaluated.

2.3.1 Bedford Workload Rating Scale

The pilots completed the BWRS (appendix A) immediately after each mission to rate the level of workload that they experienced when performing flight and mission tasks. The tasks were selected because they were estimated to have the most impact on aircrew workload during the missions.

The BWRS has been used extensively by the military, civil, and commercial aviation communities for pilot workload estimation (Roscoe and Ellis, 1990). It requires pilots to rate the level of workload associated with a task based on the amount of spare capacity they feel they have to perform additional tasks. Spare workload capacity is an important commodity for pilots because they are often required to perform several tasks concurrently. For example, pilots often perform navigation tasks, communicate via multiple radios, monitor aircraft systems, and assist the pilot on the controls with flight tasks (e.g., maintain airspace surveillance) within the same time interval. Mission performance is reduced if pilots are task saturated and have little or no spare capacity to perform other tasks. Integration of the UAS control with the AH-64D crewstation should help ensure that pilots can maintain adequate spare workload capacity while performing flight and mission tasks.

2.3.2 Visual Workload

An eye tracker was used during the evaluation to assess visual gaze and dwell times for the pilots. The data were collected to help determine how often the CPG was able to maintain visual focus outside the aircraft to assist with navigation (e.g., identification of terrain features), local security, terrain flight, etc., when having the added task of controlling an UAS. Visual gaze and dwell time data help identify whether pilots experience excessive visual workload or cognitive capture because they had problems interpreting information presented to them on the crewstation displays (for example).

2.4 Assessment of Crew Situation Awareness

SA can be defined as the pilot’s mental model of the current state of the flight and mission environment. A more formal definition is “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” (Endsley, 1988). It is important to assess SA because of its potential to directly impact pilot and system performance. Good SA should increase the probability of good decision making and performance by aircrews when conducting flight and mission tasks in the AH-64D.

2.5 Situation Awareness Rating Technique

The SART (appendix C) is a multi-dimensional rating scale for operators to report their perceived SA. The SART was developed as an evaluation tool for the design of aircrew systems (Taylor, 1989) and examines three components of SA: understanding, supply, and demand. Taylor proposed that SA is dependent on the pilot's Understanding (U) (e.g., quality of information they receive), and the difference between the Demand (D) on the pilot's resources (e.g., complexity of mission) and the pilot's Supply (S) (e.g., ability to concentrate). When D exceeds S, there is a negative effect on U and an overall reduction of SA. The formula $SA = U - (D - S)$ is used to derive the overall SART score. The SART is one of the most thoroughly tested rating scales for estimating SA (Endsley, 2000).

2.6 UAS Crewstation Interface

The UCI impacts crew workload and SA during a mission. A UCI that is designed to augment the cognitive and physical abilities of crews will minimize workload, enhance SA, and contribute to successful mission performance. To assess the UCI, the pilots reported any problems that contributed to high workload and low SA at the end of each mission. They also completed a lengthy questionnaire at the end of their final mission. The questionnaire addressed usability characteristics of the UCI.

2.7 Assessment of Simulator Sickness

Simulator sickness has been defined as a condition where pilots suffer physiological discomfort in the simulator, but not while flying the actual aircraft (Kennedy, Lilienthal, Berbaum, Balzley, and McCauley, 1989). It is generally believed that simulator sickness is caused by a mismatch either between the visual and vestibular sources of information about self-motion, or between the sensory information (e.g., acceleration cues) presented by the simulator and the sensory information presented by the primary aircraft that the pilot operates. When the sensory information presented by the simulator does not match the aircraft, the pilot's nervous system reacts adversely to the sensory mismatch and the pilot begins to experience discomfort. Characteristics of simulator sickness include nausea, dizziness, drowsiness, and several other symptoms (Kennedy et al., 1989). It is important to assess simulator sickness because the discomfort felt by pilots can be distracting. Pilot distraction is one of the operational consequences of simulator sickness listed by Crowley (1987). If pilots are distracted by the discomfort they feel during missions, their performance is likely to suffer. Additionally, the discomfort could influence the perceived levels of workload and SA that the pilots experienced during a mission.

2.8 Simulator Sickness Questionnaire

The SSQ was administered to the pilots to estimate the severity of physiological discomfort that they experienced during missions and help assess whether they were being distracted by the discomfort. The SSQ (Kennedy, Lane, Berbaum, and Lilienthal, 1993) is a checklist of 16 symptoms. The 16 symptoms are categorized into three subscales. The subscales are Oculomotor (e.g., eyestrain, difficulty focusing, blurred vision), Disorientation (e.g., dizziness, vertigo), and Nausea (e.g., nausea, increased salivation, burping). The three subscales are combined to produce a Total Severity score. The Total Severity score is an indicator of the overall discomfort that the pilots experienced during the mission.

2.9 Subject Matter Experts

Two SMEs observed each mission and rated crew workload, crew SA, and mission success. The SMEs provided an independent assessment of the workload and SA levels experienced by the crews. They also helped identify whether problems with crew workload or crew SA contributed to lack of mission success.

The SMEs were pilots assigned to the TCM RA and the AH-64D program management office. They held the rank of CW4 and each had over 3000 h of flight experience. The pilots had substantial experience conducting attack missions and were familiar with the UAS mission. They observed each mission using a suite of monitors that showed all crewstation displays and the location of the aircraft, friendly forces, and enemy forces. They also listened to all audio communications between crewmembers and outside sources (e.g., wingman, ground commander) during the missions. A SME conducted an AAR with the pilots at the end of each mission. During the AAR, the SME reviewed the positive and negative aspects of the mission to provide instruction to the pilots and develop and refine TTP.

2.10 Evaluation Design

While the evaluation was operational in nature rather than experimental, multiple variables were controlled in order to maximize the validity of the conclusions regarding the areas of evaluation. Table 1 summarizes the variables that were controlled during the simulation.

Table 1. Test variables.

Factor	Control	Conditions
Mission	Constant	Air assault
Flight profile	Tactically varied	Nap-of-Earth (NOE), contour
Light conditions	Constant	Day
Scenario	Constant	Southwest Asia
Crew	Constant	Maximize crew familiarity
Seat position	Varied	Front, back
Flight uniform	Constant	Air Warrior Gen 3 Combat-Basic

2.11 Overhead Cockpit Cameras

An overhead camera was mounted in the front seat and a small camera was mounted on the glareshield in the back seat to record pilot actions. This aided in determining what the pilots were doing during different phases of the mission. The cameras had a time stamp added so that the elapsed time could be compared with other data that was collected.

2.12 Switch Actuations

When initiated, the data collection software collected switch actuations at a 10 Hz rate. The collected data were time stamped and written to a comma delimited log file. The log file was then post-processed to an Excel spreadsheet format. The data collection software provided an interface to allow the operator to initiate and cease collection during an executed run.

2.13 Head and Eye Tracker System

CPG visual gaze and dwell times were collected through a head and eye tracking system from Applied Science Laboratories (ASL). The ASL system was used because it was capable of integrating a laser head tracker to allow unrestricted head movement during data collection and it was compatible with the integrated helmet and display sight system (IHADSS) flight helmet. The ASL Eye-Head Package included a Model 501 eye tracker and an Ascension Laserbird head tracker. This technology allowed us to collect data that specified point of gaze with respect to stationary objects (e.g., MPDs) within the CPG crewstation. The ASL software allowed data collectors to continuously monitor the eye position of the pilots by crosshairs superimposed over live imagery (figure 6). The software also included a built-in analysis tool that allowed data to be viewed in tabular or graphical format.

Figure 6. Eye tracker, pupil/camera monitors, and control panel interface.

2.14 Data Analysis

Pilot responses to the BWRS, SART, SSQ, and UCI questionnaires were analyzed with means and percentages. Their responses to the BWRS, SART, and SSQ were further analyzed with the Wilcoxon Signed Rank Test (WSRT) to compare the ratings between the CPG and pilot and between ratings for the UAS missions vs. comparable non-UAS missions to determine if the differences were statistically significant (≤.05).

The eye tracker data were summarized by calculating the total percentage of fixations that occurred for the different areas of interest (AOIs). Six AOIs were created for the CPG: right MPD, left MPD, TEDAC, keyboard, and kneeboard. Visual gaze and dwell times were also recorded for out-the-window. A final category, called "Other," captured eye fixations not focused on a specific AOI.

2.15 Evaluation Limitations

The primary limitations included the small sample size of pilots (N=10) who participated in the assessment, the limited training they received (2 days), limited number of missions they conducted, and mix of AH-64D software versions in the RACRS.

These limitations are not uncommon when replicating a complex aviation system in a simulator. However, the information and data listed in the Results and Summary sections of this report should be interpreted based on these limitations. Additional data should be collected during future simulations and tests to augment and expand the findings contained in this report.

2.16 Participants

Ten AH-64D pilots participated in the assessment. Six pilots were assigned to the 3-101 Aviation Regiment, Fort Campbell, KY; two pilots were assigned to the 21st Cavalry Brigade, Fort Hood, TX; and two pilots were assigned to the Forces Command (FORSCOM) HQ G-3 Office, Fort McPherson, GA. Nine pilots held the rank of warrant officer (CW2 = 2 pilots, CW3 = 3 pilots, CW4 = 3 pilots, CW5 = 1 pilot) and one pilot held the rank of Captain. Four pilots were rated Flight Activity Category (FAC) 1 and six pilots were FAC 2, and eight pilots were Readiness Level (RL) 1 and two pilots were RL 3. They represented a broad range of experience with total flight hours from 650 to 3875 h. The relevant demographic characteristics of the pilots are shown in table 2.

Table 2. Pilot demographics (N = 10).

Summary of Demographic Characteristics	Age (yrs)	Flight Hours in AH-64D	Total Flight Hours in Army Aircraft
Mean	36	860	1897
Median	37	750	1400
Range	25–43	550–1620	650–3875

3. Results

3.1 Crew Workload—Average Bedford Workload Ratings for Flight and Mission Tasks

The average Bedford workload rating (for all tasks) was 2.6 for the CPG and 2.9 for the PI (figure 7). These ratings indicate that the CPGs and PIs typically felt that workload was tolerable for the tasks and they had enough spare mental capacity for all desirable additional tasks. The difference in workload ratings between the CPG and PI was not statistically significant (WSRT, Z = –1.856, p = .093). This suggests that pilots perceived that workload levels were comparable for the CPG and PI during most missions.

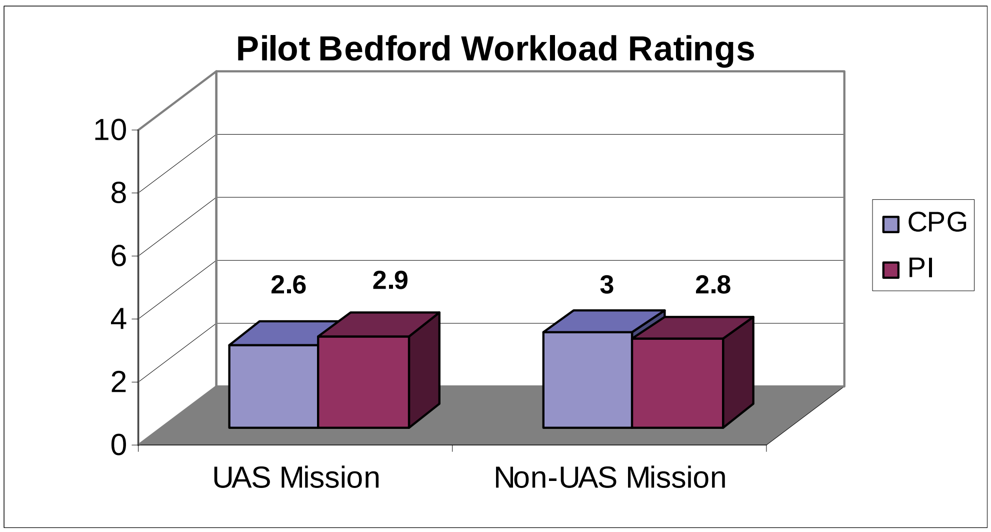

Figure 7. PI and CPG workload ratings.

The estimated average workload ratings for comparable non-UAS missions (using MTADS and/or FCR only) was 3.0 for the CPG and 2.8 for the PI. These ratings indicate that the pilots typically believed that workload was tolerable for the tasks and they had enough spare mental capacity for all desirable additional tasks when performing comparable missions without employing a UAS. The differences in workload ratings between UAS missions and comparable non-UAS missions was statistically significant for the CPG (WSRT, Z = –2.840, p = .006), but not statistically significant for the PI (WSRT, Z = –.577, p = .774). The majority of pilots commented that the workload levels they experienced during UAS missions were comparable to workload levels they experienced during missions using only the MTADS and/or FCR. They reported that having to manage an additional sensor (UAS sensor) increased their overall task workload, but the SA provided by the UAS sensor typically decreased the workload required to detect and engage targets. They stated that (1) it was easier for them to detect and engage targets using the UAS sensor because of the steep visual aspect angle ("God's Eye" view) that the UAS

sensor provided compared to the shallower visual aspect angle that the MTADS and/or FCR typically provides during missions; (2) the SA provided by the UAS sensor reduced the time required to detect and engage targets; and (3) while they had more tasks to complete because of the additional sensor, they had more time to complete target detection and engagement tasks because of the greater stand-off range that the UAS sensor provided vs. the stand-off range that the MTADS/FCR provides during missions.

3.1.1 CPG Task Shedding

The CPGs reported that there were very few tasks that they had to ask the PIs to perform (due to high CPG workload). ARL personnel observed only a few instances when the CPG asked the PI to perform a task because he was experiencing high workload. However, the CPGs occasionally shed tasks such as (responding to) radio calls, did not maintain positive control of the MTADS and let it drift into its limit stops, and asked for Level 4 control (but did not take Level 4 control) of the UAS because they were busy with other tasks.

3.1.2 Impact of Workload on Aircrew Coordination

The majority of PIs (80%) reported that the required level of crew coordination was higher during UAS missions than comparable non-UAS missions. They commented that having to manage an extra sensor increased their workload and required them to interact more with the CPG. The CPGs were split on whether having to manage an extra sensor increased the required level of crew coordination: 50% of CPGs reported that the required level of crew coordination was higher, 30% reported it was lower, and 20% reported it was comparable to a non-UAS mission.

3.1.3 SME Ratings of Aircrew Coordination

The SMEs provided ratings (figure 8) of how well the crews performed aircrew coordination tasks (e.g., positive communication) per Training Circular 1-210. The SMEs rated aircrew coordination during most missions as “Good” (50%) or “Average” (35%).

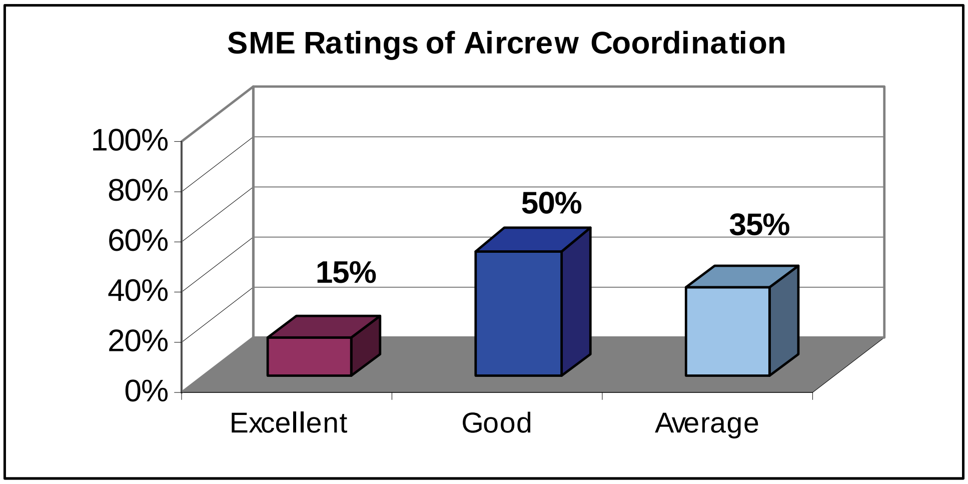

Figure 8. SME ratings for PI and CPG aircrew coordination.

3.1.4 SME Workload Ratings

SMEs provided an overall Bedford workload rating for each mission that they observed (figure 9). The average SME Bedford workload rating (table 3) was 4.9 for the CPG and 4.3 for the PI for all missions. These ratings indicate that the SMEs believed that (1) workload was tolerable for the CPG and PI but that they had reduced spare workload capacity, (2) the CPG could not give the desired amount of attention to additional tasks, and (3) the PI had insufficient spare capacity for easy attention to additional tasks. The difference in SME workload ratings between the CPG and PI was not statistically significant (WSRT, $Z = -1.806$, $p = .088$).

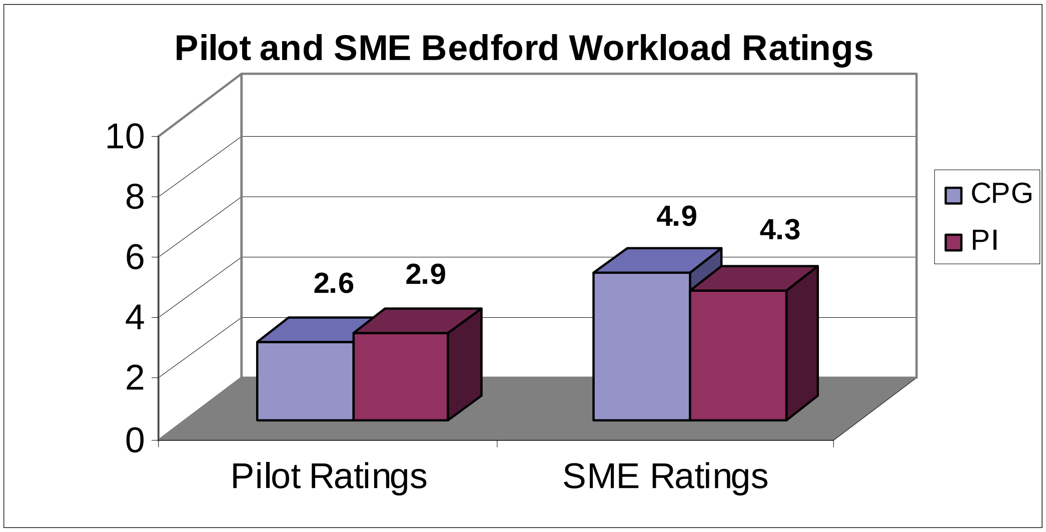

Figure 9. Comparison of crew and SME Bedford workload ratings.

Table 3. SME Bedford workload ratings.

Workload Ratings	PI	CPG	Combined
Average	4.30	4.90	4.60
Median	4.00	5.00	4.50
Standard Deviation (S.D.)	1.49	1.37	1.43

In previous simulations and operational tests that ARL has helped conduct, SMEs have typically rated pilot workload higher than the ratings provided by the pilots. SMEs have more information (e.g., location of all threat and friendly vehicles) available to them to assess pilot performance and workload than the information that the pilots have available to them. SMEs are often more aware of pilot mistakes (that may be attributable to workload) than the pilots. The additional information that the SMEs have likely results in a more critical assessment of pilot performance and workload. This area requires further study to identify the reasons why SMEs typically rate pilot workload higher than the ratings provided by the pilots.

3.1.5 Visual Workload

Figure 10 shows the average percentage of time that the CPGs were visually focused on each AOI during the missions. The CPGs were visually focused on the right MPD (UAS sensor video) for 49% of the time during missions. They were visually focused on the left MPD (Tactical Situation Display (TSD)) for 19% of the time and the TEDAC (MTADS sensor) for 14%. It is interesting to note that the CPGs typically spent only 6% of the time visually focused out-the-window during missions. The majority of CPGs (80%) reported on post-mission surveys that they were "inside" the cockpit more than during a non-UAS mission; however, they commented that the amount of time they were visually inside the cockpit was not much more than a comparable non-UAS mission. They stated that they did not believe that the amount of time they were visually inside the aircraft increased the probability of accidents. Two CPGs reported that not having the visual scene represented on the Helmet Display Unit (HDU) kept them visually inside the aircraft more than if they were able to use the HDU for tasks such as local security and navigation.

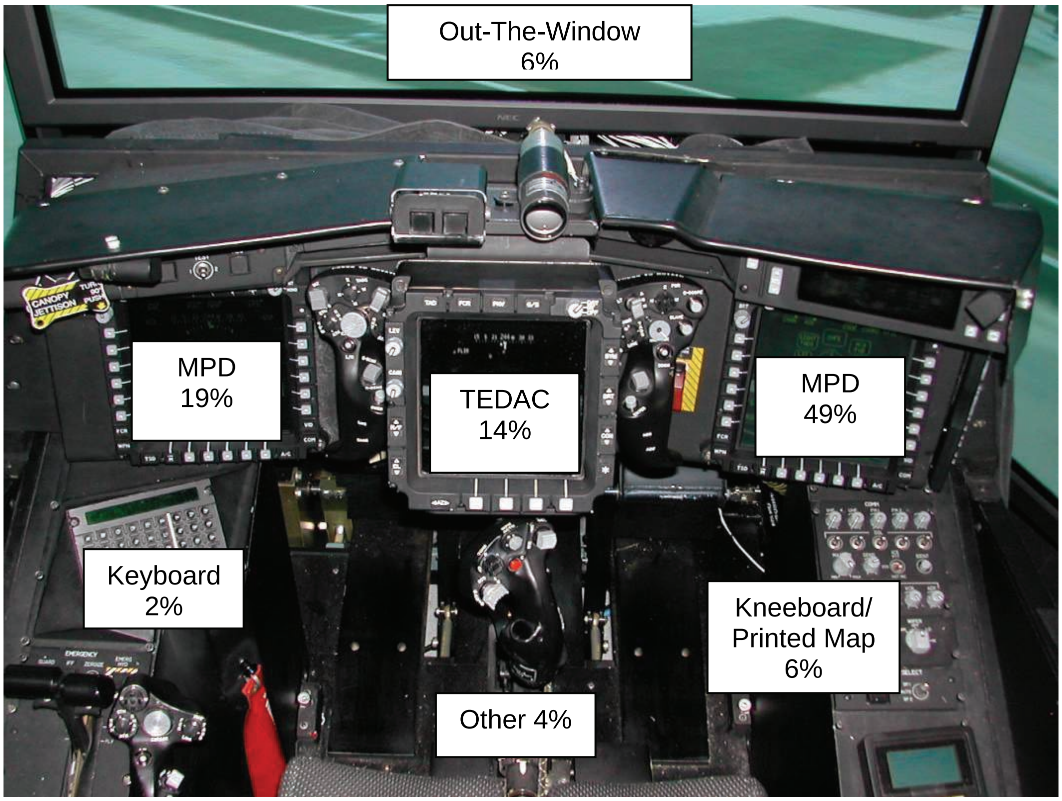

Figure 10. CPG visual gaze and dwell times during UAS missions.

One baseline mission (MTADS/FCR only, no UAS) was conducted to compare how much time the CPG was visually focused outside the aircraft during the Air Assault mission (figure 11). The CPG spent just 2% of the time visually focused out-the-window during the baseline mission. The baseline mission suggests that the amount of time that CPGs are visually focused outside the aircraft during comparable missions (e.g., day, visual flight rules) when employing the UAS and MTADS/FCR is similar to missions when employing only the MTADS/FCR.

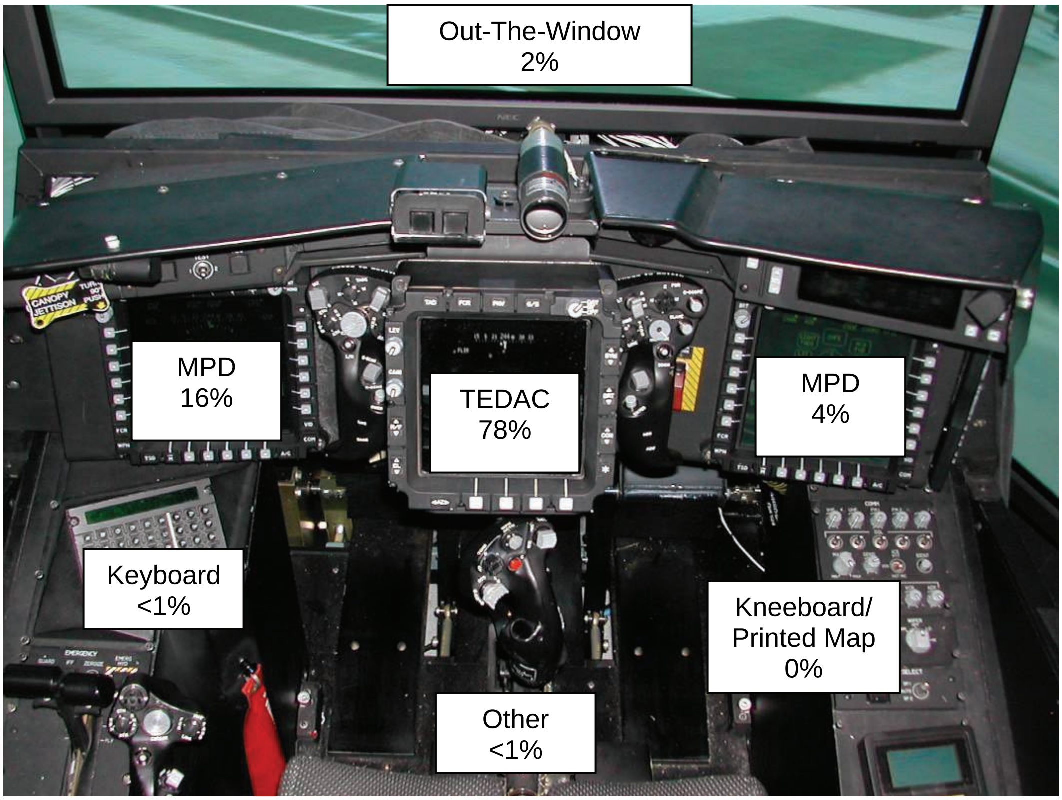

Figure 11. CPG visual gaze and dwell times during baseline mission (non-UAS mission).

The PIs were split when asked if they were "inside" the cockpit more than during a non-UAS mission: 50% of the PIs reported they were inside more than during a comparable non-UAS mission, 40% reported they were inside "about the same" as a comparable non-UAS mission, and 10% said they were inside less than a comparable non-UAS mission. A small camera was mounted on the glareshield in the rear cockpit so that ARL personnel could observe how much time the PIs spent visually focused inside vs. outside the aircraft. ARL personnel observed that the PIs were visually focused outside the aircraft approximately 75% of the time and inside 25% of the time (figure 12). The PIs confirmed the observations made by ARL personnel during post-mission discussions.

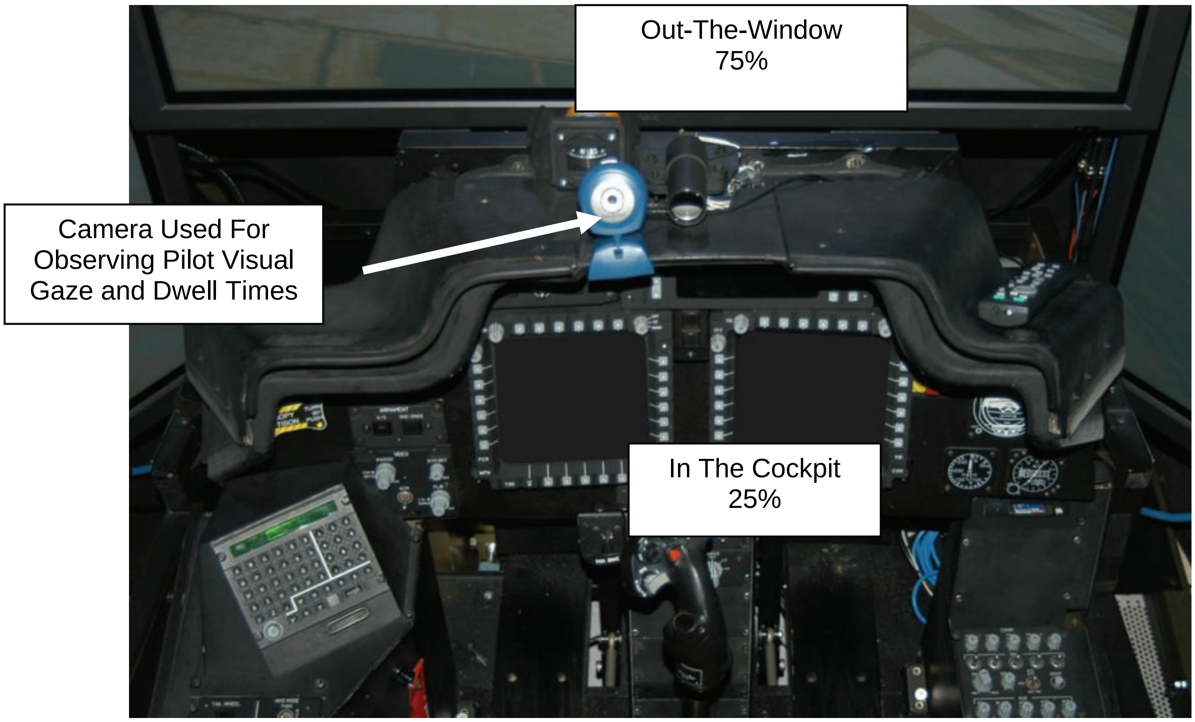

Figure 12. PI visual dwell times estimate.

During the missions, the CPGs were not able to maintain visual focus outside the aircraft to assist with navigation (e.g., identification of terrain features), local security, terrain flight, etc. For 90%+ of the time, the CPGs were visually inside the aircraft performing (mostly) target detection and engagement tasks. It should be cautioned that the simulation was conducted with a small sample size of pilots, pilots did not get all of the peripheral visual cues that they would in an aircraft, pilots know that they cannot die if they crash the simulator (vs. aircraft), and only one baseline mission (MTADS only) was conducted.

3.1.6 Comparison of Eye Tracker Data

Table 4 shows a comparison of AH-64D, Armed Reconnaissance Helicopter (ARH), and UH-60M eye tracker data for Visual Flight Rules (VFR) flight during simulations. The ARH and UH-60M simulations were conducted to assess the human factors characteristics of the aircraft as part of system development and/or operational testing. While the aircraft, missions, training, and personnel experience levels were different for each simulation evaluation, it is interesting to note the differences in visual gaze and dwell times for each evaluation.

Table 4. Comparison of eye tracker results for AH-64D, ARH, and UH-60M simulations.

	AH-64D/UAS Workload Assessment		**UH-60M Early User Demonstration 2**		**UH-60M Limited User Test**		**UH-60M Limited Early User Evaluation**		**ARH HFE-CAAS Evaluation**	
	Flying Pilot[a]	**CPG**	**Flying Pilot**	**Non Flying Pilot**	**Flying Pilot**	**Non Flying Pilot**	**Flying Pilot**	**Non Flying Pilot**	**Flying Pilot**	**Non Flying Pilot**
Outside	75%	6%	69%	N/A	86%	28%	61%	26%	61%	7%
Inside	25%	94%	31%	N/A	14%	72%	39%	74%	39%	93%

[a]Estimate from watching PI gaze and dwell times with video camera during missions (non-eye tracker).

3.2 Crew Situation Awareness—Situation Awareness Ratings

The overall SART scores provided by the pilots were 24.0 for the CPG and 25.7 for the PI (figure 13). These scores indicate that the CPG and PI felt they had moderate levels of overall SA during the missions. The difference between SART scores for the CPG and PI was not statistically significant (WSRT, Z = –.612, p= 0.572). The estimated SART scores for comparable non-UAS missions (MTADS/FCR only) were 18.4 for the CPG and 23.2 for the PI. The difference between SART scores for the UAS missions and comparable non-UAS missions was not statistically significant for the CPG (WSRT, Z = –1.620, p= 0.133) or for the PI (WSRT, Z = –1.127, p= 0.289). The pilots stated that they had higher SA during UAS missions (vs. non-UAS missions) mostly because of the "God's Eye" view that the UAS sensor video provided during missions. The UAS sensor video also gave the pilots good SA earlier in the mission (vs. non-UAS missions) because they often received the video prior (or just after) take-off of their aircraft.

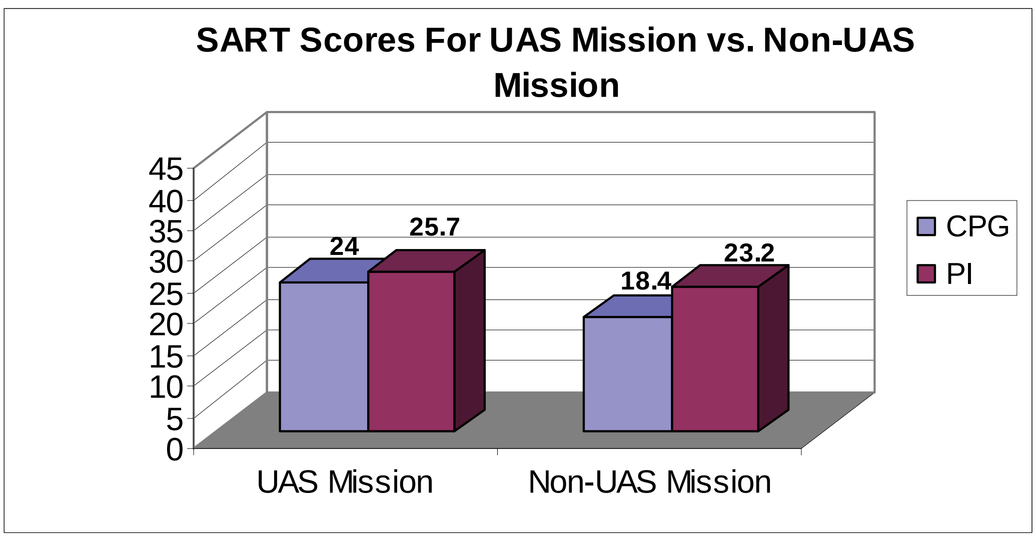

Figure 13. Overall SART scores for PI and CPG.

The pilots reported that they had high levels of SA of most of the battlefield elements (appendix C) during the missions. The battlefield elements included location of enemy and friendly units, location of own ship, location of cultural features (e.g., bridges), and route information (e.g., waypoints). However, there were several instances when the aircraft flew near (or over) the target(s) and onboard missiles were fired outside of the aircraft/UAS constraints. This was likely caused by the lack of extensive training and experience with the UAS and the need for improved cueing symbology to help pilots understand where their aircraft and the UAS are located in reference to the targets.

3.3 SME SA Ratings

The SMEs provided an independent assessment of aircrew SA based on the scale shown in table 5. The mean SMEs SA rating for aircrews was 2.40, indicating that the SMEs perceived that the aircrews typically had adequate levels of SA with minor or insignificant variation between perception and reality. The SMEs noted that there were several instances when the aircraft flew near (or over) the target(s) and onboard missiles were fired outside of the aircraft/UAS constraints.

Table 5. SME SA rating.

	SME SA Ratings
1	Crew was consistently aware of all entities on the battlefield.
2	Crew was aware of the battlefield with minor or insignificant variation between perception and reality.
3	Crew was aware of the battlefield. Variation between reality and perception did not significantly impact mission success.
4	SA needs improvement. Lack of SA had some negative effect on the success of the mission.
5	Lack of SA caused mission failure.

Mean Rating
2.40
(SD = 0.99)

3.4 SME Ratings of Mission Success and Mission Objectives

At the end of each mission, SMEs rated whether the mission was a success or failure. The criteria that the SMEs used to rate mission success or failure was whether the aircrew completed most or all of their mission objectives and did not get shot down or crash. The SMEs rated all 10 missions as "successful" (figure 14). They also rated whether the aircrew completed their mission objectives. The mission objectives were given to the pilots during the pre-mission brief. The SMEs believed that the aircrews completed their objectives during 90% of the missions. One SME rated two aircrews as not meeting all of their objectives during two missions.

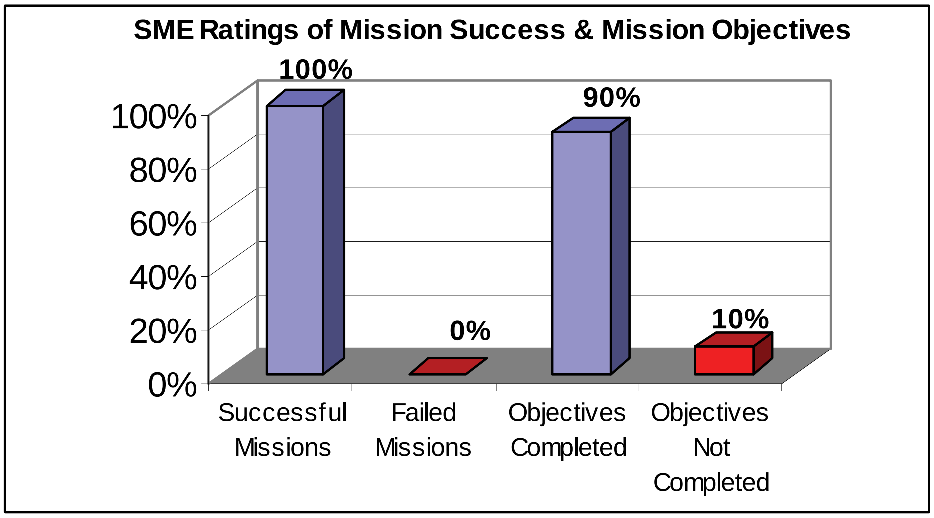

Figure 14. SME ratings of mission success and mission objectives.

3.5 UAS Crewstation Interface

The CPGs were generally favorable in their ratings of the UCI. They reported that they were able to quickly navigate through the UAS menu pages on the right MPD, quickly use the switches on the TEDAC grips and buttons on the right MPD to control the UAS, felt that the overall design of the UCI did not significantly hinder them from controlling the UAS, and reported that the UCI did not contribute to high workload. The CPGs also reported that they "Never" (69%) or "Occasionally" (29%) forgot the steps required for navigating through the UAS display pages on the right MPD and experienced some problems switching between the operation of the MTADS/PNVS and UAS sensor due (mostly) to lack of experience. However, there were several improvements that the pilots recommended be made to the UCI to increase usability and decrease workload and the time required to complete tasks. These recommendations are listed in appendix D.

3.6 Switch Actuations

Switch actuations were recorded to help determine whether there were CPG tasks (e.g., UAS menu navigation) that need to be streamlined because of excessive switch actuations. The CPGs made an average of 609 switch actuations per mission (appendix F). This equates to approximately 7–8 switch actuations per minute or one switch actuation per 8 s for each mission. The switch actuations were often clumped together within specific time intervals. The switches that were actuated most often by the CPG were the MTADS Field of View (FOV) select switch, right hand grip slave select switch, left hand grip tracker switch, left hand grip cursor up/down switch, right MPD bezel buttons, and right hand grip laser trigger. The pilots reported that they did not think that the number of switch actuations per mission was excessive. Many of the switch actuations were momentary actuations of the MTADS FOV select switch and right hand grip slave select switch.

Table 6 summarizes the number of MPD page changes per mission. The average number of right and left MPD page changes was 73 for the CPG and 69 for the PI per mission. The TSD and TCDL pages were the pages most often displayed by the CPG and PI during missions.

Table 6. MPD page changes during missions.

	Number of Page Changes Per Mission			
Mission	**CPG (Right MPD)**	**CPG (Left MPD)**	**PI (Right MPD)**	**PI (Left MPD)**
1	24	55	28	69
2	16	36	11	34
3	50	42	8	26
4	21	54	75	35
5	52	54	13	29
6	12	44	10	39
7	12	52	41	58
8	17	45	17	18
9	11	22	25	71
10	36	76	47	32
Avg	25.1	48	27.5	41.1
Std. Dev	15.53	14.15	21.36	18.38
Min	11	22	8	18
Max	52	76	75	71

3.7 Top Improvements Recommended by Pilots

The pilots recommended that several improvements be made to the UCI and UAS to increase usability and decrease workload and the time required to complete tasks. Following are the most significant improvements that the pilots recommended be made to improve UAS employment (examples for each improvement are listed in appendix E):

- Improvements to UAS Cueing Functions/Symbology
- Improvements to Display Menu Pages
- Need Linear Motion Control (LMC) for UAS
- Incorporate UAS Operator into Pre-Mission Planning
- Aviation Mission Planning System (AMPS) Integration of UAS Functionality

3.8 Simulator Sickness

Pilots reported that they typically experienced very mild to mild simulator sickness symptoms during the evaluation. The overall mean Total Severity (TS) score (post mission) for the pilots was 8.51 (table 7). The mean TS score for the CPGs was 9.72 and the mean TS score for the PIs

was 7.01. The difference between the TS scores for the CPG vs. the PIs was not statistically significant (WSRT, $Z = -.210$, $p = .875$). Based on the categorization of simulator sickness symptoms proposed by Kennedy et al (2002) (table 8), the pilots experienced "minimal" simulator sickness symptoms during the missions.

Table 7. SSQ ratings.

Condition	Nausea Subscale	Oculomotor Subscale	Disorientation Subscale	Total Severity Score (Mean)	Standard Deviation
Pre-Mission (CPG)	.095	4.54	2.78	3.36	6.22
Post-Mission (CPG)	8.58	9.09	6.96	9.72	15.88
Pre-Mission (PI)	1.19	0.94	3.48	1.87	2.82
Post-Mission (PI)	9.54	5.68	1.74	7.01	11.28
Pre-Mission CPG and PI	1.06	2.94	3.09	2.70	4.93
Post-Mission CPG and PI	9.01	7.58	4.64	8.51	13.98

Table 8. Categorization of simulator sickness symptoms.

SSQ Total Score	Categorization
0	No symptoms
< 5	Negligible symptoms
5–10	**Minimal symptoms**
10–15	Significant symptoms
15–20	Symptoms are a concern
> 20	A problem simulator

Note: Categorization of symptoms based on central tendency (mean or median) using military aviation personnel in each simulator (Kennedy, 2002).

3.9 Comparison of RACRS Simulator SSQ Scores to Other Helicopter Simulators

To assess whether the SSQ ratings provided by the pilots during the assessment were similar or different to ratings obtained in other helicopter simulators, the mean SSQ scores for the RACRS simulator were compared to the mean SSQ scores for several other helicopter simulators (table 9). The other helicopter simulators were the AH-64A (Army Research Institute, non-motion simulator), ARH-70, S-3H, CH-46E, CH-56D, CH-56F, Sikorsky RAH-66 Engineering Development Simulator (EDS), RAH-66 Comanche Portable Cockpit (CPC), and the simulator used during the UH-60M for the Early User Demo (EUD) and Limited Early User Evaluation (LEUE). In comparison, the RACRS induced fewer simulator sickness symptoms than most of the helicopter simulators listed in table 9.

Table 9. Comparison of RACRS simulator SSQ ratings with other helicopter simulators.

Simulator	Nausea Subscale	Oculomotor Subscale	Disorientation Subscale	Total Severity Score (Mean)
AH-64A[a]	–	–	–	25.81
ARH-70	18.02	21.48	9.28	20.15
SH-3H	14.70	20.00	12.40	18.80
RAH-66 EDS	11.84	14.98	4.54	13.25
CH-53F	7.50	10.50	7.40	10.00
RAH-66 CPC	3.29	12.94	7.89	9.80
UH-60M (LEUE)	6.36	11.81	3.09	9.15
RACRS	**9.01**	**7.58**	**4.64**	**8.51**
UH-60M (EUD)	13.88	6.89	0	8.50
CH-53D	7.20	7.20	4.00	7.50
CH-46E	5.40	7.80	4.50	7.00

[a]SSQ subscale data not available.

Based on pilot SSQ ratings, observation by ARL HRED personnel during missions, feedback during post mission interviews, and comparison of SSQ ratings with ratings from other helicopter simulators, it is reasonable to assume that the simulator sickness symptoms the pilots experienced did not (1) cause them significant discomfort, (2) distract them during missions, or (3) contribute to an increase in perceived workload.

4. Conclusion

4.1 Crew Workload

Pilots reported that they typically experienced tolerable workload when performing missions while controlling the UAS. They reported that the workload they experienced was comparable to workload they experience during "non-UAS" missions (MTADS and/or FCR only). They commented that having to manage an additional sensor (UAS sensor) increased their overall task workload, but the SA provided by the UAS sensor decreased the workload required to detect and engage targets and decreased overall target engagement timelines. The SMEs reported that the pilots typically experienced tolerable workload when controlling the UAS during missions, but had reduced spare workload capacity. The workload ratings provided by the pilots and SMEs were lower than the Objective and Threshold workload ratings requirements listed in the AB3 CDD (table 10).

Table 10. Pilot workload requirements and ratings.

CDD Bedford Workload Rating Requirements	Pilot Bedford Workload Ratings	SME Bedford Workload Ratings
Objective Req. – 5.0 Threshold Req. – 6.0	PI – 2.9 CPG – 2.6	PI – 4.3 CPG – 4.9

4.2 Crew Situation Awareness

Pilots typically experienced moderate levels of SA during missions. They reported that they had high levels of SA of most of the battlefield elements (e.g., threat location) during the missions. However, there were several instances when they flew near (or over) the targets and fired missiles outside of the aircraft/UAS constraints. This was likely caused by the lack of extensive training and experience with the UAS and the need for improved cueing symbology to help pilots understand where their aircraft and the UAS are located in reference to the targets. The pilots stated that they had higher SA during UAS missions (vs. non-UAS missions) mostly because of the "God's Eye" view that the UAS sensor video provided during missions. The UAS sensor video also gave the pilots good SA earlier in the mission (vs. non-UAS missions) because they often received the video prior (or just after) take-off of their aircraft. The SMEs reported that the aircrews typically had adequate levels of SA.

4.3 Crew Coordination

The majority of PIs reported that the required level of crew coordination was higher during UAS missions than comparable non-UAS missions. They commented that having to manage an extra sensor increased their workload and required them to interact more with the CPG. The CPGs were split on whether having to manage an extra sensor increased the required level of crew coordination. The SMEs rated aircrew coordination during most missions as "Good" or "Average."

4.4 UAS-Crewstation Interface

The CPGs were generally favorable in their ratings of the UCI. They reported that they were able to quickly navigate through the UAS menu pages on the right MPD, quickly use the switches on the TEDAC grips and buttons on the right MPD to control the UAS, commented that the number of switch actuations per mission was not excessive, felt that the overall design of the UCI did not significantly hinder them from controlling the UAS, and reported that the UCI did not contribute to high workload.

The pilots recommended that the following improvements should be made to enhance UAS employment:

- Improvements to UAS Cueing Functions and Symbology
- Improvements to Display Menu Pages
- Need LMC for UAS
- Incorporate UAS Operator into Pre-Mission Planning
- AMPS Integration of UAS Functionality

4.5 Simulator Sickness

Pilots reported that they typically experienced very mild to mild simulator sickness symptoms during the evaluation. The simulator sickness symptoms the pilots experienced did not (1) cause them significant discomfort, (2) distract them during missions, or (3) contribute to an increase in perceived workload.

5. Recommendations

The following recommendations are made to enhance the overall effectiveness and suitability of the UAS integration into the AH-64D:

- Address and incorporate the recommended improvements (e.g., enhanced cueing) provided by the pilots.
- Use the Crew Station Working Group to address and incorporate the recommended improvements.
- Upgrade the RACRS simulator to make it representative of the AH-64D Block 3 design to enhance future simulations.
- Maximize the amount of pilot training for future UAS evaluations.
- Use the same data collection methodology (e.g., Bedford, SART) during future simulations and tests for Apache Longbow Block 3. Standardizing the data collection methodology will help identify changes that work (e.g., changes that reduce workload), identify areas that still need more work, amd help drive continuous incremental improvements.

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Appendix A. Bedford Workload Rating Scale Scores and Pilot Comments

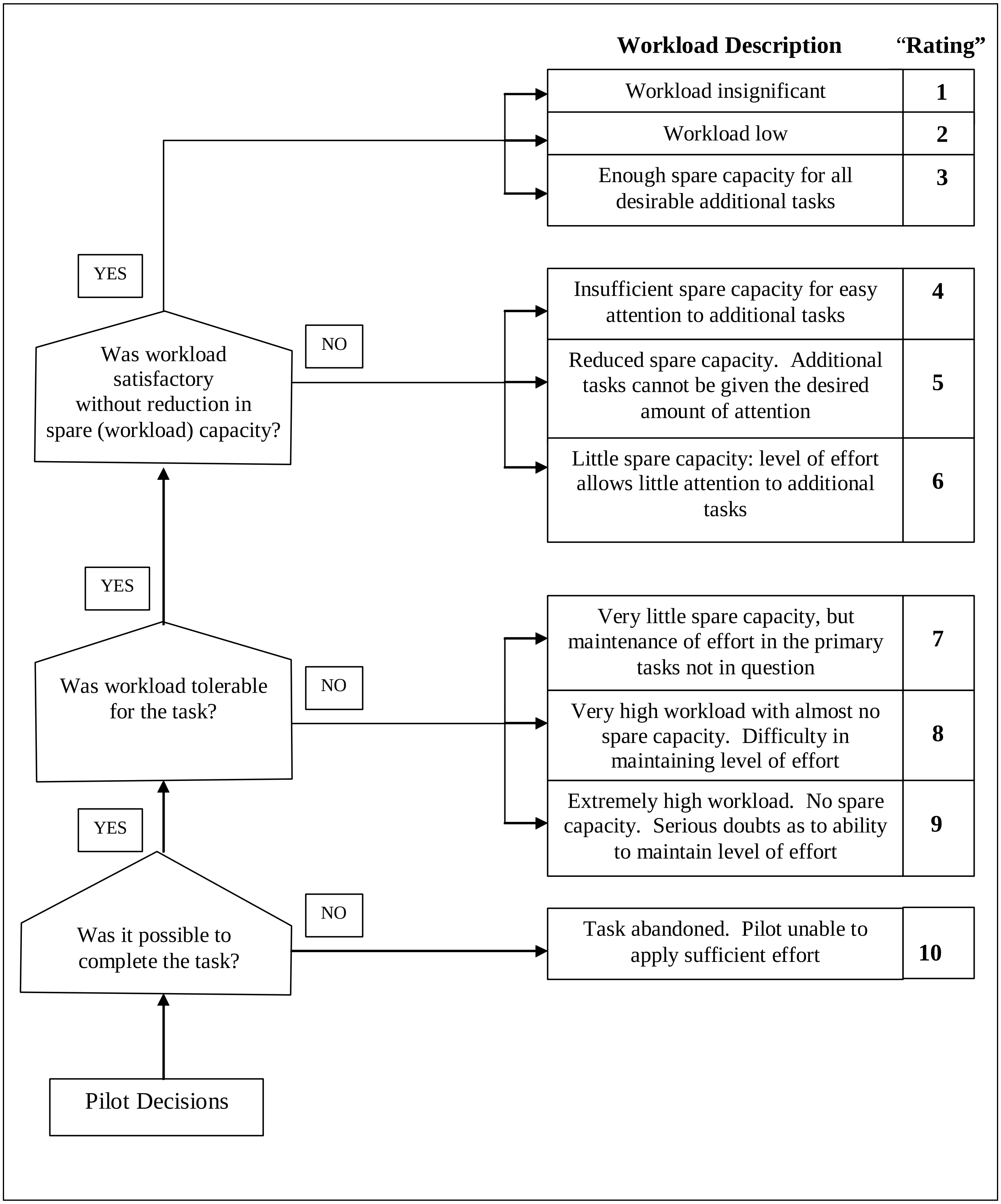

Figure A-1. The BWRS.

Table A-1. Mean Workload Ratings for UAS missions and comparable non-UAS missions.

Flight and Mission Tasks	Mean Workload Ratings for UAS Missions		Mean Workload Ratings for Comparable Non-UAS Missions	
	CPG	Pilot	CPG	Pilot
Observing Named Areas of Interest	2	2	3	3
Target Detection	2	3	4	3
Target Acquisition	3	3	4	3
Target Engagement	3	3	4	3
Movement To Contact	3	3	3	3
Actions On Contact	4	4	4	3
Battle Damage Assessment And Reporting	2	2	3	3
Mission Change	3	2	3	3
Battle Handover	2	3	2	3
Tactical Navigation (Contour/NOE)	2	3	2	2
Communications (Tactical Ops Center, Wingman)	2	3	2	2
NOE/Contour/Low Level Flight	2	3	2	2
Maintain Airspace Surveillance	3	3	3	3
VMC Flight Maneuvers	2	2	2	2
Electronically Aided Navigation	2	2	2	2
Terrain Flight Navigation	2	3	2	2
Evasive Maneuvers	3	5	4	4
MTADS/PNVS Operations	3	2	3	2
Route Recon	2	3	3	3
Area Recon	2	3	3	3
Level 2 UAS Control	2	3	–	–
Level 3 UAS Control	3	3	–	–
Level 4 UAS Control	3	2	–	–
Data Entry Procedures	2	3	2	3
Engage with Hellfire	3	4	3	4
Engage with 30mm AWS	4	2	4	2
Multi-ship Operations	3	3	3	3
Transmit Tactical Reports	3	3	2	3
Identify Major U.S./Allied and Threat Equipment	3	3	4	3
Information Management In The Front Seat (CPG)	3	–	3	–
Information Management In The Back Seat (PI)	–	4	–	3
Air Escort Mission (overall)	3	3	3	3
Security Mission (overall)	3	3	4	3
Overall Workload Ratings	Avg: 2.6 Median: 3 Std. Dev.: 0.6	Avg: 2.9 Median: 3 Std. Dev.: 0.6	Avg: 3 Median: 3 Std. Dev.: 0.7	Avg: 2.8 Median: 3 Std. Dev.: 0.5

Pilot Workload Comments

If you gave a workload rating of ‘5’ or higher for any task in the UAS mission column, explain why the workload was high for the task.

Explanations as to why the pilots assigned a rating of ‘5’ or higher for any task in the UAS column.

Evasive Maneuvers:

- Task intensive, there is no way to add additional tasks and still be capable of performing or reacting to evasive maneuvers.
- EM too task intensive to also be using UAS. Once completed or out of danger area and continuing to engage it becomes much easier.
- EM caused CPG to totally concentrate on UAV while physiological functions and visual cues in the cockpit caused visual rivalries.

Actions on Contact:

- Task intensive, there is no way to add additional tasks and still be capable of performing or reacting to actions on contact.
- All concentration goes to maintaining LOS centered on target and communicating.
- AoC too task intensive to also be using UAS. Once completed or out of danger area and continuing to engage it becomes much easier.
- Weapon engagements are always intensive.
- Difficulty maintaining SA with wingman/UAV in relation to self when engaging TGTs.

Target Detection/Acquisition/Engagement:

- All concentration goes to maintaining LOS centered on target and communicating.
- Concentrated effort of controlling the TFC (Thumb Force Control) on OBJ/TGT to maintain LOS during Hellfire engagement.
- Workload is lower for detection/identification/acquisition and engagement using the UAS. Crew can create a 3-D picture of the battle space vs. the 2-D (TADS) picture.
- CPG remains focused on TGT with UAV unable to perform other tasks until engagement is complete.
- TGT detection and Acquisition are easier with UAS; TGT engagement has a higher workload due to hellfire designation basket.

Hellfire/Rockets/30mm:

- All concentration goes to maintaining LOS centered on target and communicating.
- Increased workload due to remote hellfire basket.

Movement to Contact:

- Weapon engagements are always intensive.

MTADS/PNVS Operations:

- Note: Full MTADS (Multi-target tracking) not available. MTADS layout when controlling UAS. TFC directly located under the UAS FOV selector. Not ergonomically designed causing higher workload during TGT engagement (Target Tracking) using the TFC.

Multiship Operations:

- Unable to concentrate on wingman's location. Relied on PI for SA.

Information Management:

- Still feels like the CPG has a large workload that can be managed with an opposite crew member.

Mission Change:

- MSN changes are easier with UAS than with TADS.
- Increased workload due to decision-making process on how to maximize employment of UAS.

Other Comments:

- Processing the additional information the UAS provided, there was a heightened sense of urgency because this mission involved friendly forces on the objective.
- Difficult processing information from extra sensor.
- With legacy target ID it's (mission)?? darn near impossible.

List any flight and/or mission tasks that you had to ask your crewmember to accomplish because your workload was too high.

PI Comments:

Other Tasks:

- Workload shared by crew based on task(s).

CPG Comments:

Flight Maneuvers/Airspace Surveillance:

- There were none he “had” to do, but the PC aided in many tasks.
- All flt maneuvers and 90% airspace surveillance accomplished by PC.

Communication Tasks:

- Some communication (radio calls).
- I could have done it, but knew PC had less to do and could offer assistance.
- Change freq, change direct, de-was missile.
- Division of communication duties.

Tactics:

- Tactics (TMPR): we as a crew discussed this plan prior to initiating the maneuvers. I relied on the PI to keep my ACFT safe from wingman in relation to UAV.

Target handover/transfer:

- Briefed with PI, that he would transfer/handover TGTs I stored to wingman or ARTY to relieve the workload on CPG. This did assist, but I felt I had enough iterations in this profile/mission that I could have assisted with this task.

Hellfire/Rockets/30mm:

- 2-Hellfire missile shots. Busy assessing BDA.

Were you ‘inside’ the cockpit more, less, or about the same compared to a non-UAS mission?

PI Comments:

- Video from UAV and ensuring LOS of laser is in constraints to fire a hellfire requires a little bit more inside time, but not enough to adversely affect the ability of the pilot to remain in control of the aircraft.
- I disciplined myself outside the acft due to the CPG increased time inside.
- Helping front seat line up targets, acquire targets draws you inside similar to TADS shots when back seat is watching tads video on MPD.
- Only inside more when CPG was loosing SA. After SA was reestablished I was back outside.
- Processing UAS information.

- Heads out more today based on MSN. Some head-in time was trying to figure out what was wrong with HMD symbology-RACRS (sim) issues.
- More inside to correlate UAS data with other sensors.

CPG Comments:

- No HDU. If I had UAV video in HDU would split more attention outside.
- A little more along the route recon with the mountains. I would have slaved TADS to my helmet and reconned by eye. The UAS allowed me to recon using it instead. Better recon, but inside more.
- Obviously inside more because of the third sight. <u>However</u>, after my 4th flt. Using the system, this is becoming <u>much</u> easier and more familiar. With a <u>little</u> time, this system will be integrated into an Apache mission without <u>any</u> ill effects.
- No HDU feed, so all CPG msn tasks involved sights viewed on MPD.
- Taking advantage of greater stand-off distance to accomplish task of DIL (Detecting, Identifying, and Locating)/ Acquiring targets using sights and sensors.
- Info management: CPG task saturated.
- Level 3 control coupled with the security mission required CPG to have eyes on for the duration of the mission.
- Tracking Targets.

Was the required level of crew coordination higher, lower or about the same as a comparable non-UAS mission?

PI Comments:

- Inside cockpit a little more and coordinating our runs on target require more talking between crew members in order to ensure first time engagement success.
- Increased workload for CPG drives pilot to ensure CPG is not task overloaded. This is done by offering assistance.
- Drawn inside, so more cross talk between crews, but SA was highly increased on objective area so it seemed well worth it.
- Back up CPG when his workload increases.
- Extra sight, more information, weapons engagements are more complex with UAS as the sight.

- Additional sight adds to workload and crew coordination – comparable to FCR. However, SA is much greater with UAS than without and somewhat better than FCR.
- As with previous missions, weapons engagements were more difficult due to FS controlling other sensor.

CPG Comments:

- Higher because there were more tasks to complete. Yet had more time to complete tasks due to increased ranges and SA.
- Better SA in both seats equals less required communication, other than simple acknowledgement of same SA.
- More steps and tasks to complete, yet more time and safer distance to do them.
- Better SA for both seats = less workload.
- Lower because of a good crew briefing to include UAS ground operator.
- Keeping SA.
- Keeping weapons MGMT/SA between wingman and UAV.
- We are still having to put the AH64 wpns in constraints with UAS. Coordination is a must.
- Change of plan/mission – Aircraft positioning for proper target engagements.

In the mission you just flew, list any flight and/or mission tasks that you had to ask your crewmember to accomplish because your workload was too high:

- There were none he “had” to do, but the PI aided in many tasks.
- All flt maneuvers and 90% airspace surveillance accomplished by PI.
- I could have done it, but knew PI had less to do and could offer assistance.
- Change freq, change direct, de-was missile.
- Some communication (Radio Calls)
- Tactics (TMPR): we as a crew discussed this plan prior to initiating the maneuvers. I relied on the PI to keep my ACFT safe from wingman in relation to UAV.
- None
- Workload shared by crew based on task(s).
- Briefed with PI, that he would transfer/handover TGTs I stored to wingman or ARTY to relieve the workload on CPG. This did assist, but I felt I had enough iterations in this profile/mission that I could have assisted with this task.

- Division of commo duties.
- 2-Hellfire missile shots. Busy assessing BDA.

In the mission you just completed, were you visually 'inside' the cockpit more, less, or about the same compared to a comparable non-UAS mission (figure A-2))?

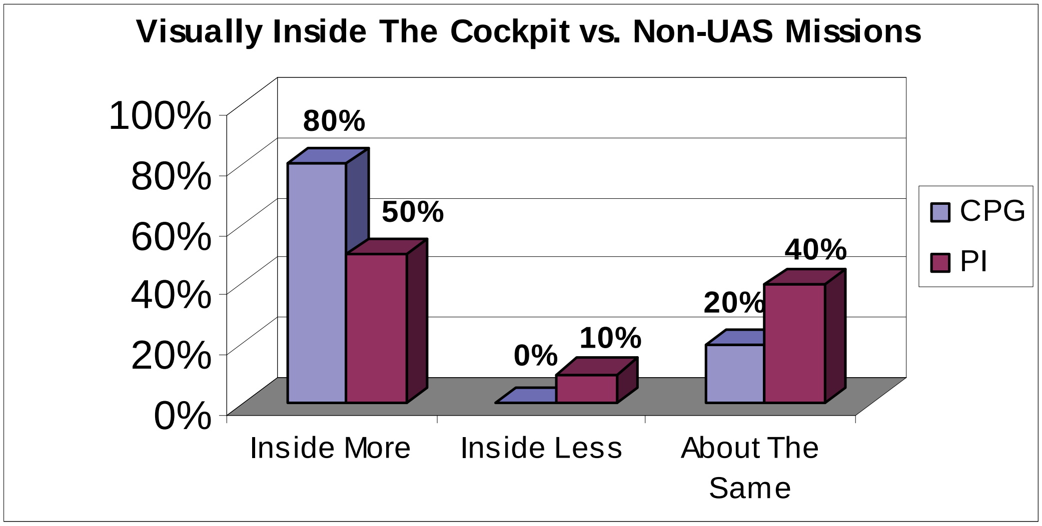

Figure A-2. Visually inside the cockpit vs. non-UAS missions.

- Video from UAV and ensuring LOS of laser is in constraints to fire a hellfire requires a little bit more inside time, but not enough to adversely affect the ability of the pilot to remain in control of the aircraft.
- As the backseater, I disciplined myself outside the acft due to the CPG increased time inside.
- A little more along the route recon with the mountains. I would have slaved TADS to my helmet and reconned by eye. The UAS allowed me to recon using it instead. Better recon, but inside more.
- Obviously inside more because of the third sight. <u>However</u>, after my 4th flt. Using the system, this is becoming <u>much</u> easier and more familiar. With a <u>little</u> time, this system will be integrated into an Apache mission without <u>any</u> ill effects.
- Helping front seat line up targets, acquire targets draws you inside similar to TADS shots when back seat is watching tads video on MPD.
- No HDU feed, so all CPG msn tasks involved sights viewed on MPD.
- Only inside more when CPG was loosing SA. After SA was reestablished I was back outside.

- Taking advantage of greater stand-off distance to accomplish task of DIL (Detecting, Identifying, and Locating)/ Acquiring targets using sights and sensors.
- Processing UAS information.
- Info management: CPG task saturated.
- Heads out more today based on MSN. Some head-in time was trying to figure out what was wrong with HMD symbology-RACRS (sim) issues.
- Level 3 control coupled with the security mission required CPG to have eyes on for the duration of the mission.
- No HDU. If I had UAV video in HDU would split more attention outside.
- Tracking Targets.
- More inside to correlate UAS data with other sensors.

Was the required level of crew coordination higher, lower, or about the same as a comparable non-UAS mission?

Much Higher level of crew coordination required – Front seat – **10%** Back seat – **20%**

Somewhat Higher level of crew coordination required – Front seat – **40%** Back seat – **60%**

About the Same level of crew coordination required – Front seat – **20%** Back seat – **20%**

Somewhat Lower level of crew coordination required – Front seat – **30%** Back seat – **0%**

Much Lower level of crew coordination required – Front seat – **0%** Back seat – **0%**

Pilot comments:

- Inside cockpit a little more and coordinating our runs on target require more talking between crew members in order to ensure first time engagement success.
- Higher because there were more tasks to complete. Yet had more time to complete tasks due to increased ranges and SA.
- Increased workload for CPG drives pilot to ensure CPG is not task overloaded. This is done by offering assistance.
- Better SA in both seats equals less required communication, other than simple acknowledgement of same SA.
- Almost same reason as 8. Drawn inside, so more cross talk between crews, but SA was highly increased on objective area so it seemed well worth it.

- More steps and tasks to complete, yet more time and safer distance to do them.
- Back up CPG when his workload increases.
- Better SA for both seats = less workload.
- Lower because of a good crew briefing to include UAS ground operator.
- Extra sight, more information, weapons engagements are more complex with UAS as the sight.
- Keeping SA.
- Keeping weapons MGMT/SA between wingman and UAV.
- Additional sight adds to workload and crew coordination – comparable to FCR. However, SA is much greater with UAS than without and somewhat better than FCR.
- We are still having to put the AH-64 wpns in constraints with UAS. Coordination is a must.
- Change of plan/mission – Aircraft positioning for proper target engagements.
- As with previous missions, weapons engagements were more difficult due to FS controlling other sensor.

Appendix B. Subject Matter Expert Workload Comments

If you assigned a workload rating of '5' or higher for either crewmember, explain why:

- Front seater shed tasks to operate UAS.
- Backseater – had good situation awareness. However, backseat was looking inside at the UAS video display during level 3&4 control to help the front seater find the targets.
- The front seat is 90% or better inside during the mission.
- Crew continuously flies within 1KM of the target area.
- Requested level 4, never took control.
- During pick up system initiation.
- CPG – did not call BN Ops back during run-up for operation update.
- CPG – launched two missiles at tgt3 → Planned rapid but sim poor video feedback.
- CPG – Asked for LVL 4, which was approved, but CPG did not take LVL 4 – remained LVL 3.
- Did crew decide to remain LVL 3 – No – CPG perceived he was in LVL 4 guide mode.
- Understanding what the UAV was doing under Level 4 control. Guide made us PROG mode – caught it after first missile. Reprogrammed a plan and then CPG selected PROG.
- Crew did not know Level 4 was in guide mode, not plan mode.
- WL-low along route to and from objective (good). Changed LVL 3 to LVL 2 to reduce workload → shifted route recon to UAS operator during MSN change – allowed CPG to setup next MSN. Remained LVL 3 control for most of the mission. CPG initially checked WPN page prior to engagement – did not check WPN page as mission progressed → CPG decided this check was not required prior to shot → Omitted task during last half of MSN.
- Front seat shed engagement tasks of storing TGTS and had difficulty re-acquiring targets.
- WAS/De-WAS weapons
- LOAL LO-DIR confusion (little)
- FXD ACQ – and driving the missile constraints bey IAT FOV TGT drives the sight when beyond the FOV

- Storing TGT not practiced – if done, this would have reduced workload of CPG having to re-acquire.
- One sim- problem increased WL when CPG tried to drop track the UAS FOV went to zoom causing the CPG to lose the TGT.
- Hellfire remote excusum and designator zones exceeded
- Crew tactic (launch UAV early) gave more time to work the targets and contributed to less stress.
- Crew members had difficulty determining their position with the position of the UAS with the targets.
- PLT loitered over the targets. Workload seemed low, but crew had an SA breakdown.
- Aircrew lost SA and flew over targets and got shot at. Crew did not maintain standoff.
- When aircrew had level 3 and 4 crew let sensor drift with no control. Crew did not use UAS ground controller to search for and designate targets. Crew shed the task of controlling UAS when they had level 3 or 4.
- PLT performed HF MSL engagements and flying ownship entered MBT WEZ several times while maneuvering.

SME Aircrew Coordination Comments:

- Crew coordination continues to improve from previous missions.
- The pilot (back seat) in this crew worked mission priorities and kept the CPG directed.
- Crew briefed engagement plan – first TGT LVL2 control – TGT destroyed.
- What were you using to line up MSL constraints? TGT as an ACQ source.
- Real good job working the cockpits.
- Very good division of Com duties.
- Excellent division of duties between MUM team.
- Very good SA in both crewstations.
- Excellent crew coordination and division of duties. Assigned tasks to UAS operator when appropriate.
- Aircrews fired multiple missiles outside the missile constraints – payload tracking – aircrew had difficulty tracking targets with UAS payload.
- PL enabled CPG to have a lower workload by performing tasks.

Describe any problems that aircrews had with situation awareness:

- TADS Operations were shed to operate UAS.
- Did not know if they had level 4 control or not.
- CPG fired second MSL with TADS FXD FWD – did you use UAS distance and HOG for MSL constraints used TGT as an ACQ source.
- Crew closed to under 1KM during gun engagement. Crew discussion to pursue target.
- Circled closer to EA-1-3KM from UAV LOS.
- Crew awareness of UAV location 64 – TGT – UAS location.
- Crew lost SA on UAV location during mission during missile engagements. Missiles 6, 7, and 8 were all outside the laser offset performance.
- Crew fired 3 missiles outside the 60deg gun target line.
- Front seat had problems knowing whether or not he had lased a weapon during missile engagements.
- Using the UAS acq should have been used to maintain TGT position – lase and store.
- Maintained excellent SA on the battle and other elements.
- Crew was prompted to hurry in when AA force holding.
- Crew prompted during AWS running foe by wingman to hurry up.
- Could not properly determine there position and the position of the UAS prior to missile engagements.
- HF missile engagement with AATF further downrange along GTL.
- Crew members had difficulty tracking with UAS payload and the crew had difficulty determining the location in regards to the UAS.
- Loitered over the targets.
- Crew over flew enemy targets. Did not maintain standoff.
- Aircrew flew within 1km of targets.

Did the aircrew complete their mission objectives?

If no, why weren't the mission objectives completed?

- Enemy forces still alive after AA inserted delayed AAGF movement to objective.
- Crew was engaged by enemy at known location.

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Appendix C. Situation Awareness Ratings and Comments

C-1. CPG

‘Demand’ During Missions

13.40

Low 1-------3-------5-------7-------9-------11-------13-------15-------17-------19-------21 High

‘Supply’ During Missions

20.50

Low 1-------4--------7--------10--------13--------16--------19--------21--------24-------28 High

‘Understanding’ During Missions

16.90

Low 1-------3-------5-------7-------9-------11-------13-------15-------17-------19-------21 High

SART SCORE: 24.0

C-2. PI

'Demand' During Missions

13.70

Low 1-------3-------5-------7-------9-------11-------13-------15-------17-------19-------21 High

'Supply' During Missions

21.80

Low 1-------4--------7--------10--------13--------16--------19--------21--------24-------28 High

'Understanding' During Missions

17.60

Low 1-------3-------5-------7-------9-------11-------13-------15-------17-------19-------21 High

SART SCORE: 25.7

Table C-1. SA of battlefield elements during missions.

Battlefield Elements	Very High Level of Situation Awareness		Fairly High Level of Situation Awareness		Intermediate Level of Situation Awareness		Fairly Low Level of Situation Awareness		Very Low Level of Situation Awareness	
	PI	**CPG**	**PI**	**CPG**	**PI**	**CPG**	**PI**	**CPG**	**PI**	**CPG**
Location of Enemy Units	**70%**	**80 %**	**30%**	**10%**	**0%**	**10%**	**0%**	**0%**	**0%**	**0%**
Location of Friendly Units	**30%**	**70 %**	**60%**	**10%**	**10%**	**20%**	**0%**	**0%**	**0%**	**0%**
Location of My Aircraft During Missions	**90%**	**80%**	**0%**	**20%**	**10%**	**0%**	**0%**	**0%**	**0%**	**0%**
Location of Other Aircraft In My Flight	**30%**	**10%**	**40%**	**40%**	**30%**	**30%**	**0%**	**20%**	**0%**	**0%**
Location of Cultural Features (e.g., bridges)	**50%**	**30%**	**40%**	**40%**	**10%**	**10%**	**0%**	**20%**	**0%**	**0%**
Route Information (ACPs, BPs, EAs, RPs, etc.)	**90%**	**80%**	**10%**	**20%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Status of My Aircraft Systems (e.g., fuel consumption)	**70%**	**0 %**	**20%**	**20%**	**10%**	**60%**	**0%**	**10%**	**0%**	**10%**

Note: BP = Battle position, EA = Engagement area, ACP = Air control point, and RP = Release point.

C-3 Aircrew Situational Awareness Comments

Describe any instances when you felt you had low situational awareness during the mission:

- Little airspace surveillance, busy mission not a lot of attention to acft systems status other than sights weapons and radios.
- Only because of probable computer sim limitations. Non-combatants and friendly forces not in a vehicle or building made it hard to determine where exactly they were at.
- Not sure where our flight escorts were and I had very little aircraft info because I did not have my HDU.
- None other than possible convoy freq and location at end.
- Wasn't monitoring acft sys or wingman much during intensive engagements.
- Difficulty finding last vehicle due to simulator issue. *** COMMENT*** Not familiar with Lot 4 load.
- Searching for last target vehicle.
- During relief-on-station due to lack of exercising the task.
- No view on non-combatants.
- CPG was too involved with mission, Required PI to update me on wingman location.
- Cultural features: I did not bother to make note of them. I was too focused on mission to care!
- *No digital capability in BFT in simulator.
- I did not hear the UH A/C depart the holding area for the LZ. Not untypical for the Lift folks MGT to make that call regardless of a UAS. They will come in based on their fuel or the ground CMDR in the A/C ordering them to do so.
- *Simulation limitation, no present pos report and BFT.
- Simulation failure of high action display caused lower SA until pilot was able to ID problem and find correct info in other sources (TSD).
- Overall: SA was much higher with UAS than without in this msn. Typically msn changes are the hardest task that a crew/team/company must perform. With the UAS, team was able to use standoff and develop the situation quicker than without the UAS.
- Determining the BDA of enemy vehicles destroyed and its position/location.

C-4 SME Situation Awareness Comments

- TADS Operations were shed to operate UAS.
- More SA was maintained. The crew used UAS efficiently to engage targets while maintaining SA.
- Did not know if they had level 4 control or not.
- CPG fired second MSL with TADS FXD FWD – did you use UAS distance and HOG for MSL constraints used TGT as an ACQ source.
- Crew closed to under 1KM during gun engagement. Crew discuss to pursue target.
- Circled closer to -1-3KM from UAV LOS.
- Crew awareness of UAV location 64 – TGT – UAS location.
- Crew lost SA on UAV location during mission during missile engagements. Missiles 6, 7, and 8 were all outside the laser offset performance.
- Crew fired 3 missiles outside the 60deg gun target line.
- Good overall SA.
- Good.
- Front seat had problems knowing whether or not he had lased a weapon during missile engagements.
- Using the UAS acq should have been used to maintain TGT position – lase and store.
- Maintained excellent SA on the battle and other elements.
- Crew was prompted to hurry in when AA force holding.
- Crew prompted during AWS running foe by wingman to hurry up.
- Could not properly determine there position and the position of the UAS prior to missile engagements.
- HF missile engagement with AATF further downrange along GTL.
- Crew members had difficulty tracking with UAS payload and the crew had difficulty determining the location in regards to the UAS.
- Loitered over the targets.
- Crew over flew enemy targets. Did not maintain standoff.
- Aircrew flew within 1km of targets.

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Appendix D. UAS-Crewstation Interface Ratings and Comments

P1. How quickly were you able to navigate through the UAS PVI menu pages (below) to accomplish a task?

	Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly
UAS Flight Mode Options (HOLD, DEST, GUIDE, PROG) on TCDL Page	**100%**				
UTIL	**80%**	**20%**			
PLAN	**60%**	**20%**	**20%**		
CODE	**80%**	**20%**			
SET	**60%**	**40%**			
TSD	**60%**	**40%**			
VIDEO	**80%**	**20%**			

P2. How often did you forget the steps required for navigating through the UAS PVI menu pages to accomplish a task?

	Frequently	Often	Occasionally	Never
UAS Flight Mode Options (HOLD, DEST, GUIDE, PROG) on TCDL Page			**60%**	**40%**
UTIL			**40%**	**60%**
PLAN		**20%**	**40%**	**40%**
CODE				**100%**
SET			**40%**	**60%**
TSD			**20%**	**80%**
VIDEO				**100%**

P3. How quickly were you able to use the switches on the grips and displays to control the UAS?

	Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly
UAS FOV	**40%**	**60%**			
Map Symbols	**75%**	**25%**			
FLIR Polarity	**100%**				
Sensor Slave	**60%**	**40%**			
Manual Tracker	**40%**	**40%**		**20%**	
Laser Trigger	**80%**	**20%**			
Sight Select	**80%**	**20%**			

If you answered "Somewhat Slowly", "Very Slowly", "Frequently", or "Often" to any of the questions, explain why you had problems (e.g., "navigating through the UAS menu pages was a slow process due to having to page through too many display screens").

- Plan- was similar to RTE menu page and thought selecting "plan 2" was enough. Kept forgetting to press R4 on top page to select plan.
- Manual tracker on system; rate should be similar to TADS.
- Lack of exercise and training.

P4. Would you be able to more quickly and easily control the UAS if the sensor image was displayed on the TEDAC vs. the right MPD?

Yes - 20% **No- 80%**

If yes, explain why it would be quicker/easier to control the UAS on the TEDAC:

- Physiologically it would be easier. Head is not turned towards right MPD constantly. It would also be natural for the CPG to use the TEDAC.

P5. Did you experience any problems switching between the operation of the MTADS/PNVS and the UAS sensor?

Yes – 60% **No – 40%**

If yes, explain the problems:

- Just had to develop muscle memory.
- Just a momentary freeze and lock up. CPG needs to double check (usually) to ensure the correct sensor needed was displayed.
- Lack of exercise (muscle memory).

P6. Was there any UAS symbology or wording depicted on the displays that was difficult to quickly and easily understand?

Yes -40% **No – 60%**

If yes, explain which symbology or wording was difficult to understand and why:

- UAV field of regard is tough and unnecessary with TSD depiction.
- The North (N) symbology should be a little brighter for SA. Occasionally, it was hard to break out from the video context.

P7. On average, how often did the design of the UAS PCI significantly hinder you from quickly and easily controlling the UASs? (Circle one)

1	2	3	4
Never – **20%**	Seldom – **80%**	Often	Frequently

If 'Often or Frequently', describe how the design of the UAS PCI significantly hindered you from quickly and easily controlling the UASs:

- Position of thumb force controller and UAS (FCR) FOV Switch. Again, with exercise (TFC Practice) this did not pose a significant problem.

P8. On average, how often did the design of the UAS PVI contribute to high workload when controlling the UASs? (Circle one)

1	2	3	4
Never – **20%**	Seldom – **60%**	Often – **20%**	Frequently

If 'Often or Frequently', describe how the design of the UAS PVI contributed to high workload during missions:

- Almost too many holding options.
- TFC sensitivity seemed too high in the RACR.

P9. Did you feel that lack of linear motion compensation (LMC) for the UAS sensor increased the time required to detect, acquire and engage targets vs. having LMC for the UAS sensor?

Significantly Increased Time – **60%**

Somewhat Increased Time – **40%**

No Difference – **0%**

If you checked ‘Significantly or Somewhat Increased Time’, explain:

- On long range 7000+ moving tgt was hard to track. Had to IAT terrain to have any fire control, which didn’t leave IAT for TGT.
- It took longer to acquire multiple targets because it forced you to use IAT which limited your ability to pan to the next target.
- LMC works great all the time for both TGT detection and engagement. I think it should have it.
- Tracking and engaging the TGTS would be much easier with this capability.
- With exercise/practice without LMC TFC is manageable. LMC will somewhat increase time due to stabilization/compensation of TFC.

P10. List any other UAS PVI usability features that hindered your performance during the missions:

- Can’t fly UAV to TGT.
- Can’t slave to WP/CM
- Lack of TGT data number when utilizing TGT store procedures. Required CPG to navigate there other MPD pages to verify if TGT was stored and which are.
    - CPG should be able to add points directly into the plan page of the UAS.
    - FLT profiles of the UAS (Racetrack, Figure 8 and Orbit) should be changed to lower values or configurable in the aircraft UAS UTIL page. The size of these profiles can limit the use of the UAS laser when engaging TGTs with missiles. Aircraft (AH64) ma need to match the UAV’s position in order to meet missile constraints. (Too much moving around to meet this requirement).
- Lack of visual cues on TSD which indicate constraints for Hellfire missile shots. (Ownship → UAS tgt visual display).
- Position of TFC and UAS FOV switch.

Appendix E. Top Improvements for UAS Integration

Top Improvements Recommended By Pilots

Improvements to UAS Cueing Functions/Symbology

- When TADS LOS is slaved to UAV LOS and 30/60 safety/laser fans are within limits horizontal and vertical, LOS symbol should change to indicate within limits. SP or WP should know both alt, pos, range, and bearing and compute for crew.
- Need symbology that allows 60deg "60-no" FQU for Hellfire
- Slave UAV LOS to waypoint/control point
- Allow UAV LOS to be slaved to any CM/WPT/HZ/TGT
- More selectable UAS symbology. To aide with SA of UAS to our aircraft.
- Allow all NAV points (WPT, HZ, CM) to be selectable for targeting the UAV sensor line of sight. AKA so I can have them for an acquisition source.
- Have range info and heading of UAS on a TSD page, added to show page in attack.
- Have range info and heading of UAS in HDU symbology.
- UAS Laser line on TSD should be - - - - (dashed) when not in range ____ (solid line) when in range and white when designating.
- When you delete an IAT gate, the LOS should stay in the field of view and at the same spot it is when the gates are deselected.
- UAS sensor indications on the TSD page (ex |-o<) like the FCR footprint.
- A dashed or solid route while in a plan.
- Add a show function on the TSD attack page to indicate heading and laser range from UAS to LOS.
- Laser range to change color when active lasing, while leaving auto green. Possibly matching Arm color.
- TGT data # symbology displayed on the UAS.
- Laser designation window (basket) on TSD. MSL constraints box should be broken until UAS and aircraft are in the basket. Likewise the laser basket should be white until all constraints are met and then go green.

- When slaving UAS to a TGT, WP, HZ, or CM that info should appear next to the point on the UAS video. Likewise, shot at (X) should appear.
- WPNS symbology (WAS'd) on display.
- When range goes from auto to laser, range should change color.
- Inverse symbology for UAV.
- Shot file should say UAS if LOS is UAS, like it does for the FLIR.
- UAS interface should work just like TADS and FCR. CAQing a TGT or icon on the TSD page should automatically make that TGT/icon the UAS AQC source.

Improvements to Display Menu Pages

- Ability to "Freeze" the UAS page (to include video) during Level 2
- Divide symbology on UAS page to have all information that pertains to UAS up top of display, information that pertains to own ship on bottom of display.
- Allow declutter of UAS symbology.
- When adding a waypoint, TGT, CM, be able to select GRID/Location by using the CAQ function.
- Have UAV video have only LOS, Laser, Field of Regard, and HAD symbology. Just like the TADS for back seat.
- When you store a target it should be hot key selectable as an acquisition source.
- Add a fully functional COORD page to the TCDL page.
- Be able to add WP/CM directly to plan page of the UAS using coordinate file or directly to plan page.
- Options for missile codes. At least 2 selectable.
- Add CORD access to UAS page at T-5
- Allow for Show options on the UAS page to allow crew member to toggle on and off parts of the display.
- LVL 3 / 4 → Freeze/Replay function
- Plan RTE building function enabling the cursor select option to input (WP, CM, HZ, TGT).

Need Linear Motion Control (LMC) for UAS

- LMC for UAV

- LMC for UAS
- Needs LMC for UAV.
- LMC for UAS Sensor
- Need LMC
- UAS Sensor package needs more stabilization and green/solid box for in-constraints.

Move UAS FOV switch to the Left Hand Grip

- UAS FOV switch should be moved to the TADS FOV (Left Hand Grip) from the FCR FOV switch. This allows CPG to maintain manual track with right hand while changed FOV's with left.
- Re-positioning of UAS FOV switch to the LHG.

Incorporate UAS Operator into Pre-Mission Planning

- Incorporate UAS crewmember in mission planning and briefs.
- Incorporate UAS ground operator with <u>all</u> inbriefs, FLT. Planning, etc.. to ensure all available TM players are situationally aware as possible. That will lighten the load for the aircraft crewmembers.

AMPS Integration

- Ability to pre-plan multiple UAS systems in AMPS before launching our mission.
- DTC/AMPS input for pre-mission planning. Routes, targets, etc…

Other Improvements

- Need the ability to send a UAS hellfire handover (UAS HO) to other aircraft. This UAS HO should constrain TGT, laser code UAS data. Once the A/C accepts the UAS HO, then the aircraft should automatically put the hellfire MSL in a remote mode. A display the laser basket (white/broken box for out of constraints and green/solid box for in-constraints.)
- With sight select UAS, the TADS should go to fixed forward just like FCR and the link function should work just like FCR.
- UAS hold pattern settings should allow for the lowest settings that each different UAS can perform.
- Multiple IAT for UAS like MTADS.
- Incorporate RFI with a UAS equipped aircraft.
- Slew rates for UAS should match more close to TADS
- allow UAV to fly to TGT.

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Appendix F. Switch Actuations

Table F-1. Switch actuations per mission.

	Number of Switch Actuations Per Mission												
Switch Description	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Avg**	**Std Dev**	**Max**
Left Hand Grip TAD FOV Select	56	24	58	60	84	119	278	24	268	58	102.9	93.72	278
Right Hand Grip Slave Select	51	13	75	76	100	82	274	34	232	66	100.3	84.79	274
Left Hand Grip Tracker Switch	60	12	20	138	74	127	86	160	106	158	94.1	53.17	160
Left Hand Grip Cursor Up/Down	0	0	39	2	74	2	1	107	252	201	67.8	92.13	252
CPG Left Bezel Buttons	57	25	46	58	62	66	61	38	39	72	52.4	14.78	72
Left Hand Grip Cursor Right/Left	0	0	19	2	42	1	1	116	181	138	50	68.63	181
CPG Right Bezel Buttons	46	31	77	35	78	40	27	24	29	53	44	19.75	78
Right Hand Grip Laser Trigger	34	34	42	31	36	43	48	66	47	48	42.9	10.28	66
Left Hand Grip Target Store	12	46	23	18	0	22	37	13	10	17	19.8	13.35	46
Left Hand Grip Weapon Select	15	12	24	14	20	3	28	8	18	4	14.6	8.21	28
UAV Field of View	8	10	0	10	24	25	6	2	6	40	13.1	12.58	40
TEDAC Gain Rocker Switch	1	0	0	0	2	11	2	0	0	1	1.7	3.37	11
TEDAC TADS Video Select	0	0	0	0	0	0	14	0	2	0	1.6	4.40	14
TEDAC Level Rocker Switch	1	0	0	0	2	6	0	0	0	2	1.1	1.91	6
TEDAC Display Brightness Rocker	0	0	2	1	1	1	1	0	0	1	0.7	0.67	2
Left Hand Grip LMC Select	3	0	4	0	0	0	0	0	0	0	0.7	1.49	4
TEDAC PNVS Video Select	0	0	0	0	0	0	6	0	0	0	0.6	1.90	6
TEDAC Display Contrast Rocker Switch	1	1	0	0	0	0	0	3	0	0	0.5	0.97	3
TEDAC Symbology Brightness Rocker	0	0	0	0	0	0	0	2	0	0	0.2	0.63	2
Left Hand Grip Scan Switch	0	0	0	0	0	0	2	0	0	0	0.2	0.63	2
TEDAC UAV Video Select	0	0	0	0	0	0	0	0	0	0	0	0	0
Left Hand Grip Sensor Select	0	0	0	0	0	0	0	0	0	0	0	0	0
Right Hand Grip Map Symbols Select	0	0	0	0	0	0	0	0	0	0	0	0	0
Right Hand Grip Sight Select	0	0	0	0	0	0	0	0	0	0	0	0	0
Right Hand Grip Enter for Cursor Control	0	0	0	0	0	0	0	0	0	0	0	0	0
Right Hand Grip Polarity Select	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	345	208	429	445	599	548	872	597	1190	859	609.2	291.16	1190

Table F-2. Time and percentage of time that menu pages were displayed on MPDs.

	CPG (Left MPD)			CPG (Right MPD)			PI (Left MPD)			PI (Right MPD)	
Time (s)	**Title**	**%**	**Time (s)**	**Title**	**%**	**Time (s)**	**Title**	**%**	**Time (s)**	**Title**	**%**
28135.4	TSD	79%	29678.1	TCDL	83%	13306.6	TSD	37%	18158.1	TSD	51%
2173.8	Wpn	6%	931.1	Wpn	3%	8780.3	TCDL	25%	12033.1	TCDL	34%
1480.1	Coord	4%	840.8	TCDL Util	2%	3930.4	Video	11%	1673.4	Video	5%
1479.8	Tre	4%	738.6	Com	2%	3878.8	Flt	11%	920.7	Point	3%
848.9	Point	2%	715.7	TCDL Plan	2%	1967.7	Eng	6%	839.9	Eng	2%
467.1	Eng	1%	709.1	Flt	2%	956.1	Wpn	3%	644.4	Tre	2%
201.6	Rpt	1%	598.3	Menu	2%	584.1	TCDL Plan	2%	497.8	DTU	1%
156.2	Map	<1%	509.7	DTU	1%	520.7	Com	1%	235	Com	1%
143	AC Util	<1%	493.2	TSD	1%	467	Tre	1%	202.2	Coord	1%
132.6	Shot	<1%	114.3	Video	<1%	366.9	Sight Boresight	1%	118.1	TCDL Util	<1%
113.4	Menu	<1%	93.8	Tre	<1%	322.1	Ctrlm	1%	82.7	TCDL Plan	<1%
108.9	Flt	<1%	63.3	Freq	<1%	126.4	WCA	<1%	82.5	TSD Util	<1%
67.9	Ctrlm	<1%	58.6	Xpndr	<1%	109	Coord	<1%	51.7	Sight Boresight	<1%
49.4	Show	<1%	42.5	ASE	<1%	64.2	Show	<1%	43.5	Rpt	<1%
32.6	Code	<1%	30.6	Map	<1%	54.6	Wpn Util	<1%	38.7	Show	<1%
25.9	TCDL Util	<1%	22.8	Show	<1%	46.3	AC Util	<1%	22.6	Route Menu	<1%
23.5	TCDL	<1%	21.5	Route Menu	<1%	45.6	Perf	<1%	19.9	Wpn	<1%
19.3	Route Menu	<1%	16.9	Wpn Util	<1%	36.5	TCDL Util	<1%	16.3	Menu	<1%
17.2	Wpthz	<1%	12.9	Code	<1%	31.6	Menu	<1%	15	Man	<1%
13.2	ADF	<1%	11.8	Man	<1%	27.7	Code	<1%	14	ASE Util	<1%
12	TSD Util	<1%	7.2	AC Util	<1%	24	ASE	<1%	13.1	Wpthz	<1%
10.5	ASE	<1%	7	Coord	<1%	22.6	TSD Util	<1%	9.1	Net	<1%
9.6	Video	<1%	6.9	WCA	<1%	20.8	Route Menu	<1%	6.4	Edit	<1%
5.4	Zn	<1%	5.2	Fuel	<1%	18.4	Fuel	<1%	6.1	ASE	<1%
4.2	Fault	<1%	5.2	Perf	<1%	14	Sys	<1%	2.8	Map	<1%
4	Wpn Util	<1%	4.1	Sinc	<1%	9.1	Map	<1%	2.7	Zn	<1%
3.6	Chan	<1%	4	Eng	<1%	8.2	Edit	<1%	2	DMS	<1%
3.5	WCA	<1%	3.8	TSD Util	<1%	7.7	Point	<1%	1.1	Flt	<1%
3.5	Fuel	<1%	3.2	HQ2	<1%	5.4	Net	<1%			
2.9	DMS Util	<1%	1.2	TCDL Code	<1%						
2.3	DMS	<1%	0.9	DMS	<1%						

Table F-3. Time of movement of switches per mission.

		Time of Movement												
Column	**Detailed Description**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Avg**	**Std Dev**	**Max**
WpnTrig	Weapon Trigger	9.3	14.1	23.4	8.8	10.2	3.4	9.9	2.4	2.1	7	9.06	6.3	23.4
TFCAz	Right Hand Grip Thumb Force Controller Azimuth	1387.7	545	901.7	1232.1	1255.3	813.2	966.5	732.9	959.7	982.6	977.67	256.1	1387.7
TFCEI	Right Hand Grip Thumb Force Controller Elevation	1490.7	531.5	957.4	1344.7	1394	832.9	1022.3	747.7	1068.7	990.8	1038.07	301.5	1490.7

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Acronyms

AAR	After Action Review
AB3	AH-64D Block III
ACP	Air Control Point
AMPS	Aviation Mission Planning System
AOI	area of interest
ARH	Armed Reconnaissance Helicopter
ARL	U.S. Army Research Laboratory
ASL	Applied Science Laboratories
ATM	Aircrew Training Manual
BP	Battle Position
BWRS	Bedford Workload Rating Scale
CDD	Capability Development Document
CPC	Comanche Portable Cockpit
CPG	Copilot-Gunner
D	Demand
EA	Engagement Area
EDS	Engineering Development Simulator
EUD	Early User Demo
FAC	Flight Activity Category
FCR	fire control radar
FORSCOM	Forces Command
FOV	Field of View
HDU	Helmet Display Unit
HRED	Human Research & Engineering Directorate

LEUE	Limited Early User Evaluation
LMC	Linear Motion Control
LOS	line of sight
MANPRINT	Manpower and Personnel Integration
MPD	Multi-Purpose Display
MTADS	Modernized Target Acquisition Detection System
NAI	Named Area of Interest
NOE	Nap-of-Earth
OneSAF	One Semi-Automated Forces
OTW	Out-the-Window
PI	Pilot (pilot in back seat who flew the aircraft)
PMO	Product Manager's Office
PNVS	pilot night vision sensor
RACRS	Risk and Cost Reduction Simulator
RL	Readiness Level
RP	Release Point
S	Supply
SASA	Situation Awareness
SART	Situational Awareness Rating Technique
SME	Subject Matter Expert
SSQ	Simulator Sickness Questionnaire
TADS	Target Acquisition and Designation System
TCDL	Tactical Common Data Link
TCM RA	TRADOC Capability Manager, Reconnaissance Attack
TCM	TRADOC Capability Manager
TEDAC	TADS Electronic Display and Control
TFC	Thumb Force Control

TRADOC	Training and Doctrine Command
TS	Total Severity
TTP	tactics, techniques, and procedures
U	Understanding
UAS	Unmanned Aerial System
UCI	UAS-Crewstation Interface
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
WSRT	Wilcoxon Signed Ranks Test

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